STANDARD GOLD MILL
(Bodie Gold Mill)
East of Bodie Creek, northeast of Bodie
Bodie
Mono County
California

HAER No. CA-299

PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

REDUCED COPIES OF MEASURED DRAWINGS

HISTORIC AMERICAN ENGINEERING RECORD
National Park Service
U.S. Department of the Interior
1849 C St. NW
Washington, DC 20240

HISTORIC AMERICAN ENGINEERING RECORD

STANDARD GOLD MILL
Bodie State Park, California HAER No. CA-299

Location:	Along the east side of Bodie Creek and at the northeast corner of the ghost town of Bodie, in Mono County, California.
Date of Construction:	1898-1899
Present Owner:	California State Parks
Present Use:	Interpretive site in the Bodie State Park
Significance:	The Standard mill is significant as an intact example of the "model California stamp mill" that developed from the flowering of nineteenth-century developments in mining and milling technologies in the wake of the California gold rush. The building represents the standard form of the California stamp mill, and it houses the full array of equipment that exemplified stamp-milling practice at the turn of the twentieth century.
Historian:	Fredric L. Quivik
Project Information:	Recording of the Standard mill was completed during summer and fall 2000 by the Historic American Engineering Record (HAER) for California State Parks, with funding provided by California State Parks and HAER. The project recorded only the mill building itself and not the ancillary buildings, such as the retort. The recording team consisted of Dana Lockett, Todd Crouteau, Christopher Marston, and Tom Behrens, all of HAER. Jet Lowe, HAER photographer, completed the large-format photography. Richard O'Connor, Senior Historian at HAER, supervised the project.

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Chapter One: Introduction

The Standard mill at Bodie, California, is an excellent example of the state-of-the-art nineteenth-century metallurgical technology developed to exploit the characteristics of gold as it is found in nature in order to extract it.

Bodie is a ghost town owned and administered by California State Parks. It is located in Mono County at an elevation of about 8350 feet above sea level.[1] Situated in a small, open basin nestled in a range of hills east of the Sierra Nevada along the California-Nevada border, the town is accessible only by dirt road. Bodie Creek flows through town from south to north, but it is dry much of the year. The ridge of hills to the east, that helps define the basin, are the location of the vein structure that held Bodie's ore body. The hills are dotted with yellow and yellow-brown piles of mine waste, which is the valueless rock that was removed from underground mine workings in the course of digging toward veins of ore (or what miners hoped would be veins of ore).[2] The piles represent the locations of mine shafts, near which may also be seen the remains of some old mine structures. Bodie's basin and the nearby hills support few trees and are covered mainly with sparse grasses and brush. The terrain is marginally useful for grazing. Given the absence of trees and Bodie's remoteness for centers of population, it appears to be an uninviting place for human habitation, unless there was some other compelling reason for people to try to live there. That compelling reason was gold.

Gold almost always occurs in nature in its native state, i.e gold is rarely chemically bound with other elements to form minerals. On the other hand, native gold, when found in nature, is almost always alloyed to some degree with silver in what may be called a solid solution. Gold that is alloyed with silver (15-35% silver) is often called electrum. Gold and silver both amalgamate readily with mercury, a property that has been a boon to the practice of extracting gold from nature. When gold exists in ore, typically quartz, in such a state that it can readily be extracted by simple amalgamation, it is called free-milling gold. Separating gold from silver is accomplished at a refinery and is of little concern to the miner. The amalgam of gold, silver, and mercury can be converted to a block of bullion by treating it in a retort, which is like a mercury still. The amalgam is placed in a furnace and heated to a temperature in excess of 400^{o} C, at

[1] U.S. Geological Survey, "Bodie, California," USGS 7.5 Minute Topographical Map (1989).

[2] The piles on the hillsides are often mistakenly called tailings piles. Tailings are the finely-ground waste product of a milling operation. In a district like Bodie, where wet milling was used, tailings are always discharged as a watery slurry. To store such tailings, they must be impounded. If tailings are not impounded, they flow downstream or they spread across the ground in a broad deposit of barely perceptible slope. The mine-waste dumps on the hillsides near Bodie are of coarse material that was piled while dry, hence their relatively steep slopes at the angle of repose for the rock of which they are composed. Tailings could not have been piled in such steeply-sloping piles without considerable effort to engineer the piles, which would have necessitated a cost that the mining companies would not have incurred.

which point the gold and silver are molten and the mercury vaporizes. The mercury vapors are captured in tubing, where they are cooled and condensed to liquid mercury, which can be re-used for subsequent amalgamation. The molten gold and silver are cast into bullion bars for shipment to the mint.[3]

Although silver also occurs in nature in its native state (often alloyed more or less with gold), it differs from gold in that it will also occur chemically bound with other elements, like chlorine or sulfur. Historically, the process for recovering free-milling silver was very like that for recovering free-milling gold. Some rich silver ore deposits, however, feature the metal in a more complex mineral, like a sulfide, in which form the silver is not amenable to extraction by simple amalgamation. Over the years, miners and metallurgists devised methods for treating silver ores, like leaching or roasting with salt, that either put the silver in solution or chemically changed the mineral so that the silver was susceptible to amalgamation. Although gold rarely presented such problems, it nevertheless was not always found as free-milling gold. Particles of gold may be coated with a thin film that prevents the mercury from wetting the gold. Gold may occur in the presence of sulfides of other metals, like iron or lead (called sulphuretes in the nineteenth century and the early twentieth), which inhibit the amalgamation of gold and mercury. Or gold may occur with elements like arsenic or antimony, which form a thin coating on the mercury and thus discourage amalgamation.[4] Such problem ores are today called "refractory," especially if they cannot be treated by cyanidation.[5]

In the first few years of quartz mining in California, miners troubled themselves only with ores that would yield gold and silver in arrastras or in stamp mills. They knew, however, that there were many "rebellious" ores that would be profitable to mine if a method, be it

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[3] General discussions of the properties of gold and gold ores may be found in Henry Louis, *A Handbook of Gold Milling* (New York: MacMillan and Company, 1894), 21-43; T. Kirke Rose, *The Metallurgy of Gold*, Second Edition (Philadelphia: J.B. Lippincott Company, 1896), 1-19; M. Eissler, *The Metallurgy of Gold: A Practical Treatise* (New York: D. Van Nostrand, 1900), 3-6; Arthur F. Taggart, *Handbook of Mineral Dressing* (New York: John Wiley & Sons, Inc., 1956), **2**-70 to **2**-73. As chemistry and the scientific understanding of the atom have developed over the past century, there has been a corresponding growth in understanding of the metallurgy of gold, which may be traced in the above texts and other from various earlier periods. For a late-twentieth-century depiction of the properties of gold, see J.C. Yannapoulos, *The Extractive Metallurgy of Gold* (New York: Van Nostrand Reinhold, 1991), 1, 11-22, 79-85.

[4] Rose, *The Metallurgy of Gold*, Fifth Edition (London: Charles Griffin & Company, Limited, 1906), 14-16, 40-41, 147-151; H.W. MacFarren, *Practical Stamp Milling and Amalgamation* (San Francisco: Mining And Scientific Press, 1910), 130-136.

[5] Yannapoulos, *The Extractive Metallurgy of Gold*, 79. Although Yannapoulos claims on p. 79 that usage of the term "refractory" is "relatively new," W.J. Adams used the term in 1899; see Adams, *Hints on Amalgamation and the General Care of Gold Mills* (Chicago: Modern Machinery Publishing Company, 1899), 109.

mechanical, thermal, or chemical, could be found to extract the precious metals.[6] Much of the technical innovation in the nineteenth century was therefore aimed at recovering gold that was not free-milling. Although various methods improved gold recoveries on some ores in some districts, a significant breakthrough with widespread application did not arise until metallurgists learned how to use cyanide in mineral processing. Potassium cyanide and sodium cyanide are among the few chemical compounds that will dissolve gold, and so cyanide became practical in extracting gold that could not otherwise be won.

The purity of gold, relative to its silver content, is measured using the unit "fine." Each unit of fine is one of a thousand units, so absolutely pure gold would be 1000 fine. The finest gold ever found was at the Pike's Peak mine, Cripple Creek, Colorado, where the gold was 999 fine. When the United States Mint was in the business of minting gold coins, it refined the gold-silver bullion it received until it was 997 fine (the remainder being silver). To make serviceable coins, the Mint then alloyed copper with the gold (nine percent copper).[7]

Chapter 2: Gold Mining in California

Nine days after the Treaty of Guadalupe Hidalgo ceded the northern half of Mexico to the United States of America, an American carpenter, living in what the Mexicans had until then called Alta California, discovered gold in the tailrace of a sawmill he was building. James Marshall found the yellow metal flakes on the morning of 24 January 1848 as he was building a mill along the American River for the prominent American entrepreneur, John Sutter. California's scattered population was soon in the grip of gold fever. As word of Marshall's discovery spread back to the United States and the rest of the outside world, the fever spread with it, triggering a remarkable migration from many corners of the globe to California, which, the reports alleged, promised untold wealth to anyone with a pan for separating the precious metal from sand and gravel. So many "forty-niners" arrived in that migration that in 1851 the U.S. admitted California as its 31st state, despite the territory being separated by thousands of miles from the other 30 states. The California gold rush is one of the seminal events in U.S. history. In a single leap the nation suddenly embraced a continent, and the social, political, economic, environmental, and cultural consequences continue to reverberate throughout America to the present.[8] More importantly, relative to the subject of this narrative, the California

[6] The term "rebellious" is used to characterize ores that were not free-milling in Thomas Egleston, *The Metallurgy of Silver, Gold, and Mercury in the United States*, Vol. I, "Silver" (New York: John Wiley & Sons, 1887), 153; and Eissler, *The Metallurgy of Gold*, 7.

[7] Egleston, *The Metallurgy of Silver, Gold, and Mercury*, Vol II, Gold and Mercury (New York: John Wiley & Sons, 1890), 696; Rose, *The Metallurgy of Gold*, Fifth Edition, 40.

[8] In anticipation of the 150th anniversary of the California gold rush, numerous books have come to press in the last few years analyzing the social, political, economic, cultural, and environmental ramifications of the California migration to the nation's history. Among them are Gray Brechin, *Imperial San Francisco: Urban Power,*

gold rush stimulated a burst of innovation in mining technologies, including an effective milling technology for winning gold from ore.[9] The Standard mill at Bodie is an excellent representative of the fully evolved California stamp mill.

During the first couple years of the California gold rush, individuals and small companies of miners staked mining claims along streams on the western slope of the Sierra Nevada. They used water to wash and separate specs of gold from fluvial sands and gravels. The miner's simplest tool was the hand-held pan. To process greater quantities of sands, a miner might use a rocker box or long Tom, but individuals were generally limited in how much material they could move through their gold gathering tools. Companies of men assembled so together they could use shovels and the flow of a stream to move larger quantities of sands through sluice boxes, which were long wooden flumes with periodic riffles along the bottom, behind which gold collected. Often companies of miners completely diverted the flow of a stream along a particular stretch by erecting a dam and a flume to convey water around the area to be worked. Then they could excavate all the sands and gravels in the bed of the stream down to bedrock. Miners found that gold tended especially to have settled near the lip of old potholes in the stream channel. Excavation down to bedrock allowed them to find nearly all the gold there was to be found. To facilitate their operations, miners installed water wheels in the flume to power pumps that elevated residual water out of the channel. The migration to California of such magnitude, however, that by the end of 1852, most of the easily excavated streamside and streambed materials had been worked.[10]

Earthly Ruin (Berkeley: University of California Press, 1999); John F. Burns and Richard J. Orsi, *Taming the Elephant: Politics, Government, and Law in Pioneer California* (Berkeley: University of California Press, 1999); Ramon A. Gutierrez and Richard J. Orsi, *Contested Eden: California before the Gold Rush* (Berkeley: University of California Press, 1999); J.S. Holliday, *Rush for Riches: Gold Fever and the Making of California* (Oakland: Oakland Museum of California, 1999); Carolyn Merchant, ed., *Green Versus Gold: Sources in California's Environmental History* (Washington, DC: Island Press, 1998); James J. Rawls and Richard J. Orsi, eds., *A Golden State: Mining and Economic Development in Gold Rush California* (Berkeley: University of California Press, 1999); Malcolm J. Rohrbough, *Days of Gold: The California Gold Rush and the American Nation* (Berkeley: University of California Press, 1997; Kevin Starr and Richard J. Orsi, *Rooted in Barbarous Soil: People, Culture, and Community in Gold Rush California* (Berkeley: University of California Press, 1999).

[9] A recent article putting California's contributions to mining technology in an international context is Roger Burt, "Innovation or Imitation? Technological Dependency in the American Nonferrous Mining Industry," *Technology and Culture* 41 (April 2000): 321-347. The classic account is Otis E. Young, Jr., *Western Mining: An Informal Account of Precious-Metals Prospecting, Placering, Lode Mining, and Milling on the American Frontier from Spanish Times to 1893* (Norman: University of Oklahoma Press, 1970).

[10] Young, *Western Mining*, 102-118; Hubert Howe Bancroft, *History of California*, Vol. XXIII (San Francisco: The History Company, Publishers, 1888), 409-412; Thomas Egleston, *The Metallurgy of Silver, Gold, and Mercury in the United States*, Vol II, 11-30; Aug. J. Bowie, Jr., *A Practical Treatise on Hydraulic Mining in California*, Tenth Edition (New York: D. Van Nostrand Company, 1905), 47-48.

Meanwhile, miners near Nevada City, California, had discovered in 1850 that there was also much gold to be found in the gravel hills flanking streams. They did not have to limit their diggings to the banks, bars, and beds of the streams themselves. These hills, although miners did not know it at the time, were the source of most of the gold they had been finding in the streambeds. Flakes of gold had been laid down in the bed of an ancient, giant river during the Tertiary period millions of years ago. That river flowed through much of what is now the northern Sierra Nevada. Subsequent smaller rivers have cut through that old bed, sorting the gravels and concentrating some of the gold at places in their own beds. Much of the gold, however, remained in the ancient river bed, which now took the shape of hills flanking smaller streams. At first miners used shovels to dig shafts into the hills, employing a method called coyote mining. In a series of backbreaking tasks, the miners hoisted gravels from the shafts and carried the material to streamside, where they could wash it and separate out the gold. The first man to devise a more efficient method to work the Tertiary gravels on his hillside claim near Nevada City was Anthony Chabot, a French-Canadian whose trade was that of a sail-maker. In 1852, he built some wooden penstocks, which delivered water to his claim under a fifty-foot head. He used the skills of his trade to make a canvas hose to run water from the bottom of the penstocks out across his claim with enough pressure to erode the ground. Aiding the force of water with his own shovel, he ran the eroded material through a ditch on his claim. Periodically, he would shut off the water so that he could clean bits of gold that had settled in the bed of his ditch. Chabot's method came to be called ground-sluicing.[11]

In 1853, Chabot and two neighboring miners devised a new method for using water to dislodge vast quantities of material from the hillsides near Nevada City. The idea belonged to Edward E. Matteson, a Rhode Islander who had sailed for California in 1849. He asked Chabot to make a canvas hose, and he got his partner, Eli Miller, a tinsmith, to fashion a tapered nozzle from a sheet of iron. The three men impounded water high above the area they wished to work, used Chabot's penstocks to develop a head of water, and conveyed the water under pressure to their mining claim through Chabot's canvas hose. They sprayed the water against a hillside through Miller's nozzle, thereby concentrating the force of the water and allowing them to wash much more sand and gravel through their sluice than they could using shovels or other earth-moving methods then available. The method came to be called hydraulicking, and its use spread throughout California's gold country. As a result, millions of tons of debris (the term for the sands and gravels washed loose by hydraulicking) were eroded into the Sacramento River and its tributaries. Hydraulicking led to several new and important developments in California history. Companies formed expressly to build dams, reservoirs, ditches, and flumes to supply miners with the water they needed. Innovators experimented with new materials that could convey water under ever greater pressure, thereby increasing its erosive force. Other innovators worked to improve the design of the nozzle, now called a monitor, through which to play water on the

[11] Holliday, *Rush for Riches*, 202-212; Robert L. Kelley, *Gold vs. Grain: The Hydraulic Mining Controversy in California's Sacramento Valley* (Glendale, CA: The Arthur H. Clark Company, 1959), 24-27; Philip Ross May, *Origins of Hydraulic Mining in California* (Oakland, CA: The Holmes Book Company, 1970), 33-34, 40-41.

hillsides, culminating in 1870 with the development of the "Little Giant," a moveable monitor that allowed miners to spray as much as a ten-inch stream of water against a hillside several hundred feet away.[12]

As hydraulic mining spread across the western slope of the Sierra Nevada, it fostered numerous small mining camps. Those camps in turn fostered a burgeoning agricultural economy in the fertile valleys of the Sacramento River and its tributaries, predicated initially on supplying the mining communities with provisions. Within a decade of the advent of hydraulic mining, those farmers began to complain of the damage being done to their farmland by the tremendous volumes of debris or slickens (another name for the sands and gravels washed through the hydraulic mining operations) carried downstream, especially during spring or storm run-off.[13] Those complaints culminated during the last quarter of the nineteenth century in a series of high-profile court cases, which severely curtailed the practice of hydraulic mining in California. That history is beyond the scope of this project.[14]

As placer mining grew more sophisticated in the transition from simple pans, rockers, and sluices to mammoth hydraulic excavations, another type of mining gradually emerged that turned gold mining in California into a truly industrial enterprise. Called quartz mining, the method had two salient characteristics: digging gold-bearing rock from the earth, and crushing that rock mechanically to expose and recover particles of gold locked within. Placer miners believed that the gold they were mining had probably originated in similar rock, that aeons ago the rock had weathered and eroded, and that subsequent fluvial action had deposited the gold in the alluvial beds they were working. The putative source rock was called the "mother lode," i.e. the vein of gold-bearing rock somewhere upstream from which the placer gold had eroded.[15] Almost from the beginning of the California gold rush, many miners abandoned their gravel diggings to search

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[12] May, *Origins of Hydraulic Mining in California*, 40-50; Kelley, *Gold vs. Grain*, 27-42; Young, *Western Mining*, 125-131; Bancroft, *History of California*, Vol. XXIV (San Francisco: The History Company, Publishers, 1890), 645-646.

[13] The debris from hydraulic mining is sometimes also called *tailings*. In this report, however, the word *tailings* is reserved for the by-product of a milling operation, in which ore is mechanically crushed to a fine size. In the process of hydraulic mining, the sand and gravel is not reduced to a smaller size other than by the incidental breaking that may occur in the course of particles moving against each other.

[14] Kelley's *Gold vs. Grain* is the definitive history of California's hydraulic mining controversies.

[15] Adolph Knopf, *The Mother Lode System of California*, U.S. Geological Survey Professional Paper No. 157 (Washington, DC: Government Printing Office, 1929), 4-5. As described in an earlier paragraph, the actual source of the placer gold in the streams along the western slope of the Sierra Nevada was the ancient bed of the large river in the Tertiary Period. As Knopf describes, however, the notion of a mother lode for California's placer persisted among miners for several decades in the nineteenth century. Early expressions of the "mother lode" theory for the origins of California's placer deposits may be seen in John S. Hittell, *Mining in the Pacific States of North America* (San Francisco: H.H Bancroft and Company, 1861), 54, 60-61.

for the mother lode. Many such miners indeed found veins of gold-bearing quartz, but when they did, they had to resort to new methods to win the gold from the earth. Digging into solid rock required more than a shovel. Miners drilled holes in the rock, set explosive charges in the holes, and blasted large blocks of rock loose. Miners hauled or hoisted the blasted rock out of the earth on their backs, in carts, or in buckets. Once they brought the rock to the surface, miners had to crush it, recover the gold, and dispose of the remainder. If they could do all these things at a cost less than the price they received for the gold, then the miners had themselves an ore deposit. If the cost of wresting gold from the earth exceeded the price the gold fetched, then the rock from which it came was simply that: rock.[16]

Although the technological development of hardrock (underground) mining is important in its own right, the set of developments of concern to this narrative is that involving the treatment of ore, once it was extracted from the earth, to yield gold. California and its previous sovereign, Mexico, had been part of the Spanish colonial world, which had its own strong tradition of treating ore. The Spanish used a simple arrastra (arrastre) or its mechanical variant, the Chile or Chilean mill, to crush ore. An arrastra could be built largely of local materials. It had a wood post planted at the center of a stone floor, on which the miner placed a layer of ore. An arm extended from the post out beyond the perimeter of the floor. One or more stones, called mullers, were attached by chain to the arm. A horse hitched to the outside end of the arm would walk in circles around the perimeter of the arrastra, dragging the arm and the stone(s) across the ore, crushing it. When mercury was added to the crushed ore, it would amalgamate with the gold and settle into the crevasses between the stones of the floor. The Chile mill featured one or more wheels, rather than crude stones, that rolled across the ore to crush it.[17]

Neither the Spanish nor the Mexicans had undertaken any mining of note in Alta California, but many miners from Mexico joined the early California gold rush and used Spanish methods to treat gold ores. These Spanish methods were predecessors to significant developments in ore treatment that arose in California in the wake of the discovery at Sutter's mill, notably the various amalgamation pans that arose as improved versions of the arrastra. Although not widely used for crushing ores in California, the arrastra did play a significant role in the opening of mining districts elsewhere in the American West. As American miners spread from California into other territories, they learned that the arrastra was a device that would allow them to crush a district's ore in advance of the arrival of mechanization and with little capital.

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[16]" An *ore* is a solid [mixture of minerals] containing a valuable constituent in such amounts as to constitute a promise of possible profit in extraction, treatment, and sale." Taggart, *Handbook of Mineral Dressing* (1956), **1**-01.

[17] Hittell, *Mining in the Pacific States*, 155-157; Almarin B. Paul, "Beginning of Quartz Mining in California," *Mining and Scientific Press* 76 (29 January 1898): 108; Rodman W. Paul, *California Gold: The Beginning of Mining in the Far West* (Cambridge, MA: Harvard University Press, 1947), 135-136; Young, *Western Mining*, 69-72.

The Chile mill remains to this day as an important device for crushing materials in the mineral industry.[18]

The beginnings of quartz mining in California in 1850 featured the stamp mill, based on northern European sources, rather than Spanish methods. A stamp mill is similar to a mortar and pestle. Indeed, the vessel holding the ore being crushed is called a mortar. Rather than by the rotating pressure of a pestle, however, the ore is crushed by having the heavy stamp dropped on it in the mortar repeatedly. To mechanize the repeated lifting of the stamp and dropping it on ore, a rotating cam shaft typically lifts the tappet on the stem of the stamp. A battery of stamps dropping in a single mortar can all be lifted by a single cam shaft. Agricola, in his 1556 treatise on mining, *De Re Metallica*, illustrated such an arrangement featuring five stamps being lifted by a water-powered cam shaft.[19] The method spread throughout Germany and by the early seventeenth century was also widely used in Cornwall. The technology imported by American miners was often called the Cornish stamp. It had been used in quartz mines of the southeastern U.S. for several decades prior to its adoption by California miners in the early 1850s. The Cornish stamp mill typically had four stamps per battery. The stem or shaft of each stamp had a rectangular section. At the bottom of each stem was a head of cast iron. The head gave the stamp is great weight, and its bottom side provided the crushing surface that dropped on ore sitting in the bottom of the mortar.[20]

There are various claims for the first stamp mill in California. One was put in operation in 1850 by John Burnett of Mariposa County, where California's first quartz vein was discovered. It had several mortars, each with but a single stamp of about 300 pounds. The next year at Grass Valley and Nevada City, both in Nevada County, several parties built stamp mills. W.J. Wright of Grass Valley built a four-stamp mill in January 1851. His stamps had wooden stems. Stanford, Fisk & Company built a similar mill on the Cosumnes River at about the same time. By the end of the year, a handful of other stamp mills had also been built in Nevada County. Typically, they had wooden stems, and each stamp weighed about 500 pounds. Early mill operators simply ran the crushed pulp through riffled sluice boxes to recover the gold.[21] From these crude beginnings an important metallurgical industry grew. The technological advances of the industry are described below. The remainder of this section will summarize the spread of

[18] Young, *Western Mining*, 69-72, 75, 193, 214, 236, 239; Taggart, *Handbook* (1956), 5-130 to 5-132.

[19] Georgius Agricola, *De Re Metallica*, translated by Herbert Clark Hoover and Lou Henry Hoover in 1912 (New York: Dover Publications, Inc., 1950): 284.

[20] Henry Louis, *The Dressing of Minerals* (New York: Longmans, Green & Co., 1909), 156-158; Paul, *California Gold*,133-134.

[21] Almarin Paul, "Beginning of Quartz Mining in California," 108; C.P. Stanford, "Origin of the California Stamp," *M&SP* 76 (29 January 1898): 107; Bancroft, *History of California*, Vol. XXIII, 414-415.

quartz mining throughout California.

The number of quartz mills in California grew steadily through the 1850s. In 1854, even as placer mining was in decline, there were 39 stamp mills operating. Two years later, there were 59. By the close of 1858, the number had jumped to 279. Unlike placer operations, quartz mining required a significant capital investment. The average cost of a stamp mill in the 1850s was about $12,000, and additional capital was needed to develop an underground mine sufficient to supply the mill with ore. The lure of wealth from quartz-mining schemes attracted investments from throughout the U.S. and from England as well. But the economic reality of the enterprise was harsh; it was estimated that ninety percent of the early quartz-mining operations failed shortly after they started.[22]

With most of the easily won gold in California already mined, and with the investment of capital in more complex hydraulic or quartz operations proving risky, many miners living in the initial camps grew anxious to find wealth elsewhere. A new destination appeared east of the Sierra Nevada in 1859 with the discovery of rich silver ore deposits in what came to be called the Comstock Lode of Nevada. Thousands of Californians and much of their capital flocked to Nevada. The vein mining undertaken in Nevada required large investments and spawned a business structure different from the norm in California, where most enterprises were owned by individuals or partnerships. In Nevada, corporations formed formally to sell shares of stock to investors who would help capitalize the mines. San Francisco became the main center for the buying and selling of Nevada mining stocks, drawing investments not only from across California but from throughout the U.S. and Europe as well. Success on the Comstock Lode emboldened Californians to spread throughout the western regions of the continent, lending their expertise to develop mining districts in Idaho, Montana, eastern Oregon, elsewhere in Nevada, as well as in southern California. Each new mining district followed the general evolutionary progression outlined in California, with prospectors first finding riches with their pans, attracting other individuals who built rockers or sluice boxes to process more gravels, followed by partnerships and companies that developed the industrial infrastructure for hydraulic or quartz mining. It was in the course of this new exploration that prospectors found the gold deposits in 1859 that formed the basis for the Bodie district along California's eastern border.[23]

The Bodie district is discontiguous with the California's primary quartz mining areas, and its discovery and development occurred later. In the 1860s and 1870s, Grass Valley and Nevada City, both located in the drainage of the South Fork Yuba River (Nevada County), were

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[22] Paul, *California Gold*, 143-146; Bancroft, *History of California*, Vol. XXIII, 416-417.

[23] Rodman Wilson Paul, *Mining Frontiers of the Far West, 1848-1880* (New York: Holt, Rinehart and Winston, 1963), 37-55; Paul, *California Gold*, 179-191; Warren Loose, *Bodie Bonanza: The True Story of a Flamboyant Past* (Las Vegas: Nevada Publications, 1979), 12-13.

California's principal quartz-mining towns. There was also intensive quartz mining along a narrow belt known as the Mother Lode. From the north end near Georgetown in Placer County, the belt extended 120 miles south-southeast along the west slope of the Sierra Nevada to Mariposa in Mariposa County. The richest portion of the Mother Lode was a ten-mile stretch in Amador County around Sutter Creek and Jackson. By the mid-1860s, though, quartz was not yet the main source of gold in California. California was still the nation's leading producer of precious metals in 1866, producing an estimated $25,000,000 worth of gold and silver. Of that, about $2,000,000 came from easily-won surface placers, perhaps as much as $9,000,000 came from quartz operations, and well over half came from the deep placers extracted by hydraulicking. Early quartz mines employed relatively crude stamp mills, but the technology began to improve greatly in the late 1860s, when some miners returned from the Nevada silver mines, where pan amalgamation and the chlorination process (see below) had been greatly improved for the recovery of precious metals from more complex ores. Those improvements fostered more permanent communities, based on an industrial order, in the vicinities of ore bodies Nevada County and the Mother Lode belt, and many of the mines continued to be productive well into the twentieth century.[24]

A mineral resource that was fortuitous for California's gold-mining industry was the cinnabar deposit in Santa Clara County near San Jose. Cinnabar is the sulfide of mercury, which was an important aid to placer mining and nearly essential to the recovery of gold from quartz ores. Prior the cinnabar discovery in California, there were no sources of mercury in North America of significance. Mercury (a.k.a. quicksilver) had to be imported from one of three major mines elsewhere, one of which was located at Almaden, Spain. A Mexican discovered the California cinnabar in 1845 and named the location New Almaden. Lacking the capital to develop the resource, however, he sold the mine to a company dominated by English capitalists. As the California gold rush soon created a significant market for quicksilver, San Franciscans came to control the New Almaden Company. California gold also spurred prospecting for other cinnabar deposits, and several were found in the 1850s and 1860s both north and south of San Francisco Bay.[25]

California's location on the west coast of North America, far from the industrial centers of the U.S. and Europe helped stimulate a significant industrial base in San Francisco predicated on supplying the mining districts of California (and soon much of the American West) with mining

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[24] Knopf, *The Mother Lode System*, 4-7; Paul, *Mining Frontiers*, 92-93; Clarence A. Logan, *Mother Lode Gold Belt of California*, Department of Natural Resources, Division of Mines Bulletin No. 108 (Sacramento: California State Printing Office, 1924), 8-12; J. Ross Browne, *Report of J. Ross Browne on the Mineral Resources of the States and Territories West of the Rocky Mountains* (Washington, DC: Government Printing Office, 1868), 8. Note that Bancroft published an identical version of Browne's report under the title, *Resources of the Pacific Slope: A Statistical and Descriptive Summary* (San Francisco: H.H. Bancroft & Company, 1869).

[25] Paul, *Mining Frontiers*, 272-277; Bancroft, *History of California*, Vol. XXIV, 656-658.

equipment and supplies. Enterprises sprang up in San Francisco and nearby cities for the

manufacture of such staple provisions as biscuits and beer as well as supplies in demand in the mining districts, like explosives and mining and milling equipment. Factories producing the latter had their origins in foundries started by forty-niners lured by the news of John Marshall's discovery at Sutter's mill. Three Donahue brothers had rushed to California from Scotland, but failing to find gold they turned to their true skills as blacksmiths, built a crude blast furnace in San Francisco, and began casting iron parts. They were followed shortly by Henry Stow, a foundryman from Chicago. When he heard the news of Marshall's discovery, he loaded his entire foundry business on a boat and shipped it down the Great Lakes and the St. Lawrence River, south across the Atlantic Ocean, through the Straights of Magellan, and along the Pacific Coast to San Francisco. Shortly after unloading his equipment in 1850, Stow again prepared it for transport, moving his foundry to Sacramento, where he operated for fourteen years. Several other foundries and machine shops soon opened, and from these beginnings grew such important suppliers to the mining West as Fulton Iron Works, Union Iron Works, Risdon Iron Works, Joshua Hendy Iron Works, and the Pelton Water Wheel Company.[26]

As manufacturing industries arose in northern California's major cities to supply the mining industry, so arose an industrial society in the permanent quartz-mining communities. The boom towns of the first years of the California gold rush had exhibited a remarkable degree of egalitarian organization. Miners were establishing communities and claims to private property well in advance of a formal governmental infrastructure. Out of a need to maintain order, miners organized to govern themselves, laying a precedent for much of subsequent California law and for the ways that new mining camps elsewhere in the West organized themselves. As miners exhausted the placer gold, many boom towns quickly went bust, but where quartz deposits supported the transition to industrialized hardrock mining, an industrial social order quickly evolved featuring several distinct classes. They included distant mine owners of the mining companies that employed resident mine managers, a large class of miners who were wage-earning employees of the companies, a mercantile class who supplied miners and their families with food, clothing, and other necessities, a class of skilled tradesmen like carpenters and blacksmiths who served a broad clientele, and a diverse service class including teamsters, household servants, prostitutes, and liveries. Within these communities evolved a full array of religious, governmental, and fraternal institutions like churches, schools, and labor unions.[27] The

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[26] Bancroft, *History of California*, Vol. XXIII, 68-101; Lynn R. Bailey, *Supplying the Mining World: The Mining Equipment Manufacturers of San Francisco, 1850-1900* (Tucson, AZ: Westernlore Press, 1996), 8-10.

[27] The classic study of the early organization of mining camps, albeit overly enthusiastic, is Charles H. Shinn, *Mining Camps, A Study in American Frontier Government* (New York: Alfred A. Knopf, 1948 reprint of the 1885 edition published by Scribner's). On the development of industrial society in California's permanent mining communities, see (in addition to latter chapters of Paul, *California Gold*, 197-341) Ralph Mann, *After the Gold Rush: Society in Grass Valley and Nevada City, California, 1849-1870* (Stanford, CA: Stanford University Press, 1982); Laurie F. Maffly-Kipp, *Religion and Society in Frontier California* (New Haven, CT: Yale University Press,

industrial pattern was well established in California and Nevada by the time the Standard mine was discovered at Bodie and the town embarked on a brief period as one of California's important mining centers.

Chapter Three: The Bodie Mining District

The Bodie mining district is located in Mono County, which was organized in 1861 with the silver-mining town of Aurora the county seat. During the 1863 survey to establish the boundary between Nevada and California, however, it was discovered that Aurora was actually in Nevada. County officials loaded their records onto wagons and hauled them to Bodie, establishing temporary offices in a hotel and saloon. Bridgeport soon became the Mono County seat. About the same time, most of the placer mines scattered throughout Mono County were depleted, so its population dwindled until 1877, when the Standard Mining Company proved the value of its recently acquired Bunker Hill-Bullion mine. Gold mines in the Bodie district grew to such prominence in the 1880s that in 1886 Mono County ($3,385,000) was second only to Nevada County ($3,700,000) in California gold production ($18,200,000 total).[28]

A. Geology

Bodie's mineral belt extends from north to south through a range of hills that extend from Bodie Bluff and High Peak (later called Standard Hill) on the north to Queen Bee Hill on the south. Along that range are the saddle at the east end of Green Street and Silver Hill. The principle mineral in the range is trachytic diorite-andesite, igneous rocks that contain feldspar and date from the late Tertiary period, about 9,000,000 years ago. During that volcanic period, there were lava flows as well as eruptions that generated pyroclastic deposits of tuff breccia. After that activity, several well-defined vents helped form intrusive dikes, plugs, and domes of volcanic material. Some of the feldspar has degraded, leaving the clay deposits that are common throughout the Bodie hills. Faulting of the earth's crust has caused extensive fissures throughout the range. Over geological time, the fissures filled with quartz and mineralizing solutions that gave rise to the ore deposits exploited during Bodie's historical period. The system of fissures is about two miles long, north to south, and about 3,600 feet wide. Geologists believe that the quartz filled the faults, resulting in their mineralization, shortly after the Tertiary period. The resulting mineral deposits were concentrated in three areas along Bodie's mineral belt: 1) in the vicinity of Bodie Bluff and High Peak, 2) in the vicinity of the saddle, and 3) in the area between Silver Hill and Queen Bee Hill. About 90% of the ore mined in the Bodie district came from the Bodie Bluff/High Peak area. Fracturing of the rock continued after the period of mineralization,

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1994).

[28] Bancroft, *History of California*, Vol. XXIV, 652-653; Glenn Chesney Quiett, *Pay Dirt: A Panorama of American Gold-Rushes* (New York: D. Appelton-Century Company, 1936), 429.

leaving cracks as deep as 300 feet and wide enough that the drafts they carried could extinguish a

candle in the mine workings. The more recent fissures were especially prominent in the Bodie Bluff area.[29]

The breccia covering much of the Bodie hills meant that few of the veins had visible outcrops. This contributed to the delay, described below, between the discovery of gold at Bodie in 1859 and the recognition of its significant promise as a quartz-mining district in the mid-1870s. The fissures and resulting veins of ore are nearly parallel to the system's north-south axis, but they gradually grow closer together at depth. Early mining companies hired experts to try to assess the Bodie orebody. Noteworthy among them were the prominent nineteenth-century professors of geology, William Blake and Benjamin Silliman. The remarkable vein structure of the Bodie orebody led early geologists studying the Bodie ore deposit to predict that the veins would converge somewhere beneath the range of hills. Mining at depth showed, however, that valuable minerals rarely extended below 500 feet from the surface. Miners also noted that the silver content of the gold ore increased with depth, leading some to predict that, if the vein structure continued at depth, Bodie would eventually become a silver-mining camp rather than one known for its gold.[30] That also did not happen.

H.A. Whiting of the California State Mineralogist's office was the first to produce an extensive report on Bodie's geology after the boom of the late 1890s. His work therefore benefited from being able to study much more extensive workings beneath the surface. Whiting pointed out that, although Bodie was known as a gold-mining camp, because most of the wealth it produced was from gold, the camp actually produced more silver by weight. He used the 1882 annual report of the Standard Consolidated Mining Company to illustrate. That year, Standard ore yielded an average of $34.28 per ton worth of gold and only $4.07 per ton worth of silver. By weight, however, the ore yielded 1.65 oz. per ton of gold and 3.14 oz. per ton of silver. The difference, of course, stemmed from the fact that in 1882 gold sold for $20.6718/oz. while silver

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[29] Charles W. Chesterman, Roger H. Chapman, & Clifton H. Gray, Jr., *Geology and Ore Deposits of the Bodie Mining District, Mono County, California*, Division of Mines & Geology, Bulletin 206 (Sacramento: California Department of Conservation, 1986), 2, 16-18, 24; Harold W. Fairbanks, "The Mineral Deposits of Eastern California," *M&SP* 73 (12 December 1896): 481, (19 December 1896): 501; R.P. McLaughlin, "Geology of the Bodie District, California," *M&SP* 94 (22 June 1907): 795; R. Gilman Brown, "The Vein-System of the Standard Mine, Bodie, Cal.," *Trans. AIME* 38 (1908): 357; Frank S. Wedertz, *Bodie, 1859-1900* (Bishop, CA: Chalfant Press, 1969), 132-141.

[30] H.A. Whiting, "Mono County," in *Eighth Annual Report of the State Mineralogist for the Year Ending December 1, 1888* (Sacramento: State Printing, 1889), 385; Wedertz, *Bodie, 1859-1900*, 132-141; Joseph Wasson, *Bodie and Esmeralda* (San Francisco: Spaulding, Barto & Co., 1878), 10-19; Fairbanks, "The Mineral Deposits of Eastern California," 481, 501; Chesterman, et al, *Geology and Ore Deposits of the Bodie Mining District*, 31.

fetched only $1.2929/oz. Whiting added that the Standard's native gold was about 675 fine, meaning that particles of gold were alloyed with silver amounting to more than 30% by weight.

The Standard's ore also contained native silver, both as flakes and wire, as well as the silver minerals argentite and kerargyrite.[31]

In 1896, Standard ore arrived at the mill in five types: 1) hard, ribboned quartz with feldspar; 2) clay bearing fragments of the ribboned quartz; 3) soft, crumbling quartz; 4) crystalline, semi-vitreous quartz; and 5) quartz mixed with manganese oxide. Gold was relatively coarse in the semi-vitreous quartz, but it was very fine in the other types of ore.[32]

B. Mining

Waterman S. Bodey, Terrance Brodigan, and E.S. Taylor were to the first to discover what they thought was placer gold on the east side of Silver Hill in 1859. They had been staying in Monoville, where gold had been discovered in July 1859. In the fall, they embarked with others on a prospecting trip through the country where Aurora and Bodie would soon arise. Finding promising colors along the divide of the Bodie hills, the party resolved in late November to return to Monoville and spend the winter. Bodey and Taylor changed their minds, however, and decided to turn back toward the hills where they had found gold and spend the winter in a crude cabin they had built at what is now the east end of Green Street. Bodey died of winter exposure, however, before he was able to reach the cabin. Brodigan and the rest barely made it through a harsh storm back to Monoville.[33]

The camp that arose around the trio's discovery was named in Bodey's honor, albeit with a change in spelling. Following news of the discovery, miners from Monoville and elsewhere, armed with pans and rockers, headed to the area that would become Bodie in the spring of 1860. As had become miners' practice throughout the West, which lacked a pre-existing order established by the state or federal government, they quickly met among themselves and organized Bodie as a mining district. The early miners used spring run-off to establish placer mining operations, and they quickly began digging into the hillsides in search of gold in gravel that could be run through their rudimentary placer equipment. Much of the gold-bearing material the miners found was weathered quartz that had not yet eroded down to the creek bottoms. To free the gold, they had to crush the rock in hand-held mortars or between large stones. The finds

[31] Whiting, "Mono County," 389.

[32] R. Gilman Brown, "A Bodie Gold Stamp Mill," *E&MJ* 61 (27 June 1896): 615.

[33] Loose, *Bodie Bonanza*, 13-18.

suggested that the hills bore promise for hardrock mining and milling. Lack of water, difficulties in mining and crushing quartz, and frequent news of gold discoveries elsewhere made it difficult to attract miners and capital to Bodie in the early years.[34]

The Bodie Bluff Consolidated Mining Company, of which Leland Stanford was president, was Bodie's first corporation in 1863, but the company invested little in development and soon failed. Nevertheless, several other companies soon followed, each acquiring lode and placer claims, millsites, and spending more or less capital on development of their properties. Because of the scarcity of water around Bodie proper, some early miners claimed water rights in Bodie Canyon or in nearby gulches, built arrastras there, and hauled their ore by wagon several miles to their arrastras for crushing. The Empire Company of New York was incorporated in 1864 to consolidate several of the early companies and their claims. With more capital for development than its predecessors, the Empire was the first company to erect and operate a mill, moving the Fogus mill from Aurora to Bodie in 1864, but the enterprise failed by 1868. Through the 1860s and 1870s, several individuals and small companies continued to explore claims on Bodie Bluff and other hills near Bodie, working their ore with crude mills and arrastras and occasionally earning some profits, but the camp languished generally. Many claims changed hands, and new companies formed. One important company, the Syndicate Mining Company, incorporated in October 1875 and acquired the old Empire mill. Two years later, when the newly organized Standard Mining Company began hoisting ore from its Bunker Hill-Bullion property, it sent its ore to the Syndicate mill for treatment, proving the wealth of the Standard's orebody. The following year, the Standard built its own stamp mill at Bodie. There followed a boom in new companies incorporated to develop other properties in the Bodie district, and a sudden rush of capital flowed to Bodie to underwrite development.[35]

Some of the companies with claims along what proved to be Bodie's mineral belt found rich gold deposits, the value of their stocks grew wildly, and they paid their investors generous dividends. The gold craze, however, induced investors to gamble on outlying properties as well, and these proved great disappointments.[36]

Milling technologies had improved considerably in the dozen years between the beginning of the Empire's effort at Bodie and the construction of the Standard mill in 1878. The improvements stemmed from extensive experience and experimentation around Grass Valley and California's Mother Lode and on the Comstock Lode and other Nevada mining districts. The improvements are described in the next chapter. The Syndicate's 1877 earnings from treating the Standard's ore allowed it to up-grade its mill in 1878 from sixteen to twenty stamps. For a few

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[34] Wedertz, *Bodie, 1859-1900*, 126-129.

[35] Wasson, *Bodie and Esmeralda*, 7-10; Wedertz, *Bodie, 1859-1900*, 129-131, 175-178; Whiting, "Mono County," 383.

[36] Wedertz, *Bodie, 1859-1900*, 148-151.

years thereafter, the Syndicate operated profitably on its own ore as well as Standard ore.[37]

Other companies that erected stamp mills shortly after the Standard strike included the Bechtel Mining Company in 1878 (bought later in 1878 and operated thereafter by the Bodie Mining Company); the Noonday Mining Company in 1879; the Spaulding Mining Company in 1879-1880; the Standard and Bulwer companies, which jointly built and operated the Standard-Bulwer mill in 1879-1880; and the Bodie Tunnel Company in 1880. The Noonday and the Standard-Bulwer were the largest of the Bodie mills at thirty stamps each, and the Noonday was increased to forty stamps in 1881. The Miners' mill, built by the Mono Mill and Mining Company in 1878, and the Silver Hill mill, built by the Silver Hill Mill and Mining Company in 1880, were established as custom mills, meaning they treated ore for other mining companies. The first generation of mills employed what had become the conventional California stamp battery, amalgamating plates or aprons, and a variety of blanket sluices and settling boxes to capture additional gold not recovered on the aprons by amalgamation. Concentrates from the sluices and settlers were then treated in amalgamating pans. Sand tailings and slimes were discharged from the mills into or toward Bodie Creek. Some companies, like the Standard, established impoundments to save tailings for possible future re-treatment, since tailings assays showed that considerable gold was still leaving the mills unrecovered. Despite the efforts of some companies to save their tailings, enough flowed down Bodie Creek that in the 1880s Wagner and Gillespie built a mill in Bodie Canyon to re-treat tailings that had moved that far downstream.[38]

Following the Standard strike, Bodie went into its brief boom period. The output of gold increased each year in the years 1877-1880, and each year the Standard Company's gold output represented more than half the district's total. The Standard mine shipped $784,523 worth of bullion in 1877, $1,025,385 in 1878, $1,448,845 in 1789, and $1,858,763 in 1880, for a total of $5,117,515. Bodie's total output during that period was valued at $8,547,301. Bodie's population is said to have peaked in 1879 at 7,000-9,000, when as many as 50 mines were operating. But decline came quickly as ore in many mines depleted. The Bodie Mining Company suspended dividend payments in 1880. The Noonday and Red Cloud companies failed in 1882. In 1883, Bodie's population was estimated at about 2,500. By 1888, only three mines were operating, the Standard was the only company milling ore, and that was in its half of the Standard-Bulwer mill, not in the Standard mill. Only about 500 people still lived in Bodie.[39]

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[37] Wasson, *Bodie and Esmeralda*, 31-32; Wedertz, *Bodie, 1859-1900*, 178-181.

[38] Wasson, *Bodie and Esmeralda*, 32-33; Wedertz, *Bodie, 1859-1900*, 183-188; Edward Eysen (illustrator and publisher), "Map of Bodie Mining District, Mono County, California" (San Francisco, 1880).

[39] Russ and Anne Johnson, *The Ghost Town of Bodie: As Reported in the Newspapers of the Day*, (Bishop, CA: Chalfant Press, 1967), 89; Whiting, "Mono County," 382-383, 394.

Circumstances stabilized around 1890, when Arthur Macy demonstrated that Bodie's low-grade ores could be treated profitably using Frue vanners (see below) to concentrate the pulp before amalgamation and when a Mr. Moore began experiments leaching the Noonday tailings.[40] These two practices--treating low-grade ores effectively and re-treating tailings--put Bodie on a fairly level economic footing for about a quarter century, although the camp never again achieved the remarkable output of gold seen during the boom years just prior 1880.

Many of the mills established at Bodie were actually constructed of equipment dismantled from other districts after their decline and hauled to Bodie in the wake of the Standard strike. Likewise, as some of Bodie's mining properties went into decline in the 1880s, the associated mills were dismantled and sold to companies in other newly developing districts.[41]

C. Community

During Bodie's boom period, it developed a reputation as a rough and tumble town around which much of Wild West lore was fabricated. During the winter of 1877-78, in addition to three general stores, six restaurants, a tin shop, shoemaker, and a few other business, Bodie had more than a dozen saloons and a like number of brothels. A year later, there were said to be nearly 50 saloons. In addition to hard drinking and gambling, the town was known for fights and shootings. Winters were particularly odd. Because of Bodie's high elevation, harsh winter weather, and remoteness, businesses had to store large supplies to last the season. Once snow isolated the town, prices went up with the uncertainty of when shipments could resume in the spring. Cold weather forced the mines to lay-off some of their workers, so newspapers reported hundreds of unemployed men who populated the drinking and gambling establishments.[42]

Because Bodie is located in high, open country, fuel presented an early problem to miners, especially after the Standard Mining Company struck its rich vein in 1877. In the absence of streams with sufficient flow for water power or of nearby coal deposits, the only practical fuel source was wood hauled from the east slopes of the Sierra Nevada or the hills around Bridgeport. Several entrepreneurs turned their attention to supplying Bodie with its lumber needs rather than trying to strike it rich by finding gold. Bodie residents needed sawn lumber for erecting buildings, they needed wood to keep warm during the town's bitter winters, and the mines needed vast quantities of wood to stoke their boilers year round. One of the first such men was N.B. Hunnewill, who built sawmills near the timber and then freighted sawn

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[40] Henry De Groot, "Mono County," *Tenth Annual Report of the State Mineralogist for the Year Ending December 1, 1890* (Sacramento: State Printing, 1890), 337-338.

[41] Wedertz, *Bodie, 1859-1900*, 188.
[42] Johnson, *The Ghost Town of Bodie*, 21-31.

lumber as well cords of firewood to Bodie. He established his business in the 1860s. In early years, wood was freighted on wagons drawn by teams of horses or mules. The distances and costs prompted several innovative solutions, including that implemented by the partnership Langly and Annas. In 1880, they bought a San Francisco Bay steamboat named the *Rocket*, dismantled it, shipped the parts by rail to Carson City, Nevada, and then hauled it overland 120 miles to Mono Lake. After rebuilding the *Rocket*, Langly and Annas sold it to James Stuart Cain, who used it to move barges of lumber from the far side of Mono Lake to the north side nearest Bodie. Cain became a leading wood dealer in Bodie. The tremendous demand for firewood and the uncertainty of the severity of winters led to some wild speculation and high prices in the lumber business supplying Bodie.[43]

Bodie's lucrative lumber market attracted the attentions of H.M Yerington and others, who began acquiring tracts of public-domain timber land near the south side of Mono Lake from the federal government in 1879. In 1881, Yerington joined with Seth and Daniel Cook, principals in the Standard Mining Company, to incorporate the Bodie Railway and Lumber Company with the intention of cutting timber on their land, erecting a sawmill there, and then shipping both sawn lumber and cordwood by rail to Bodie. Yerington was president of the new company. Construction of the narrow-gauge line began in June 1881. The line ran 31.6 miles between a 12,000-acre tract of timber land southwest of Mono Lake to the east side of the saddle between Bodie Bluff and Silver Hill. Although the Bodie terminus was some distance from the townsite proper, it was convenient to the various companies' hoisting works along the mineral belt. In August, the company's sawmill on Mono Lake was ready to operate, and it began cutting ties. The community that grew around the sawmill was called Mono Mills. In September, by which time locomotives and rolling stock had begun to arrive, the grading of the right-of-way was complete, and the laying of ties and track began. The company bought the *Rocket* to ferry rails and other supplies across the lake to the construction area. Crews drove the last spike on 14 November 1881, and that day a train delivered two carloads of lumber to the Standard mine. When the Bodie Railway and Lumber Company began delivering wood to Bodie, J.S. Cain and a partner named Stewart became Bodie's main wood dealers, putting all but a few of the other small wood dealers out of business almost immediately.[44]

From the time the Bodie Railway and Lumber Company's line opened, there were hopes that eventually Bodie would have a connection to an outside line in the nation's system of railroads, but such a link never occurred. The company was renamed the Bodie and Benton Railway and Commercial Company in 1882, indicating the owners' intention of extending the line south to Benton, California, where it would reach the Carson & Colorado Railroad. The Bodie and Benton surveyed its extension and even graded nine miles of the route from Mono

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[43] Emil W. Billeb, *Mining Camp Days* (Berkeley, CA: Howell-North Books, 1968), 45; Wedertz, *Bodie, 1859-1900*, 154-158; Johnson, *The Ghost Town of Bodie*, 51.

[44] Billeb, *Mining Camp Days*, 45-46; Wedertz, *Bodie, 1859-1900*, 155-161; Johnson, *The Ghost Town of Bodie*, 50-54.

Lake toward Benton, but there work ceased. The project was never completed. Without outside connections, the company never established passenger service. After Bodie's boom of the early 1880s ended, the railroad went into decline, and by 1890 all the rolling stock had been sold. The little shortline made a recovery in 1893 and continued to serve as Bodie's source of lumber until it closed in 1917, when the mines were in decline and electricity had been the main source of power for the mines and mills for two decades.[45]

Nearly all Bodie's buildings, commercial and residential alike, were built of pine. Although not as important in volume as cordwood to feed the boilers at the mines and mills, sawn lumber was nevertheless another important part of the market for wood during Bodie's boom. Observers were amazed at the town's chaotic mix of buildings ranging from nice residences to shanties and from substantial businesses to brothels. As the town grew, it extended to the south, and most of the new business blocks gathered along the south end of Main Street, which ran north-south just west of Bodie Creek. By June 1879, in addition to all the business buildings, Bodie boasted lodges for the Oddfellows and Masons, two banks, a school, but no churches. When Bodie's decline began after 1880, the chaotic north end of town was the first to be abandoned, so that by 1890, when Bodie had become nearly a one-company town (the Standard), most of the businesses were concentrated along Main Street near the corner of Green. In addition to the Standard Company, one of Bodie's prominent business factors was J.S. Cain, who had bought half-interest in one of the banks in 1888. He bought the other half-interest in 1892 and continued banking there for forty years. He also was the Wells Fargo agent until it discontinued express service to Bodie in 1912.[46]

Chapter Four: The Development of Gold Milling Technology

Milling is a process of ore reduction whereby the extraction of the valuable metals is effected at a minimum of expense. Gold stamp milling is that particular process in which a heavy cylindrical body of iron is made to fall upon the ore in such a manner as to crush it, and thereby facilitate a separation between gold and the valueless minerals by which the gold is encased. The latter weigh less than the former, and are removed by the aid of water. The gold is then collected through the agency of mercury with which it readily forms an alloy or amalgam. From this combination it is finally extracted by the distillation or retorting of the mercury.[47]

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[45] Billeb, *Mining Camp Days*, 35-36; Wedertz, *Bodie, 1859-1900*, 161; Johnson, *The Ghost Town of Bodie*, 49, 54; De Groot, "Mono County," 336.

[46] Billeb, *Mining Camp Days*, 82; Johnson, *The Ghost Town of Bodie*, 26-30; Eysen, "Map of Bodie Mining District," 1880; "Bodie" (New York: Sanborn-Perris Map Company, 1890).

[47] T.A. Rickard, *The Stamp Milling of Gold Ores* (New York: The Scientific Publishing Company, 1897),1.

> The modern mill, the Californian stamp-mill as it is appropriately called, differs not at all in ultimate principle from its predecessor of four centuries ago, but all its details haveu undergone extensive modification.[48]

The first of these comments--by T.A. Rickard, a leading authority on American mining industry and technology--summarizes the principles of gold milling as they were understood at the close of the nineteenth century. The second--by Henry Louis, professor of metallurgy at the University of Durham in England and a leading authority on ore milling equipment at the end of the nineteenth century--articulates the widely-held appreciation that those principles of gold milling had reached their highest expression in the practice of the California stamp mill. The Standard mill at Bodie, built in 1898, is an excellent representative of the California stamp. This section will summarize the history of its development.

There are two basic stages of a gold-milling operation: crushing the ore finely enough to expose particles of gold, and separating the gold from the rest of the crushed material. In a fully-developed, nineteenth-century California stamp mill, crushing usually took place in two stages: coarse crushing in a Blake jaw crusher or similar device, and fine crushing by stamps. Recovery of gold was accomplished by amalgamation with mercury. Each of these parts of the process enjoyed significant development during the early years of the gold and silver era in California and Nevada, so that the stamp mill was a fully-developed technology by 1870.

The Blake jaw-crusher was one piece of a mill's equipment that did not have its origins in the metal-mining industry. Its inventor, Eli Whitney Blake, was the nephew of his namesake, the famous American inventor of the cotton gin and developer the concept of interchangeable parts in the manufacture of firearms. After graduating from Yale in 1916 and beginning to study law, Blake went to work for his uncle instead, taking over the Connecticut firearms business with his brothers when Whitney died in 1826. From that base, they moved into the manufacture of hardware. In the 1850s, while a member of a committee supervising a road-construction project, Blake conceived of a machine that could effectively break rocks to produce a crushed-rock road-surfacing material. The machine featured two jaws, one fixed and one moveable. A lever, driven by a crankshaft, caused the moveable jaw to open and close, crushing rocks into smaller bits. Blake received a patent for the machine in 1858. The first use of a Blake crusher in the mining industry was at the Benton mill on the Merced River in Mariposa County, California. The machine was shipped by boat around the southern tip of South America. Prior to installation of the Blake crusher, the mill had employed 25 Chinese laborers, who used sledge hammers to break ore to a size suitable for feeding the stamp batteries. After an extension of the patent expired in 1879, numerous manufacturers began producing rock crushers based on the Blake scheme, refining it in various ways to suit specific applications. Several prominent San Francisco manufacturers of mining and milling equipment made their own versions of the Blake

[48] Louis, *A Handbook of Gold Milling*, 108.

crusher.[49]

As stated above, the process of crushing ore with stamps was employed in Europe as early as the sixteenth century, and miners the Carolinas and Georgia had been using stamps for several decades prior to the California gold rush. Conventional stamps in 1850 had wooden stems or shafts of square or rectangular section. This meant that the iron head of the stamp dropped in exactly the same position each time, causing greater wear on some portions of the surface of the head and less on others until the head was rendered relatively ineffective. Isaac Fisk, a machinist working with C.P. Stanford's stamp mill on the Cosumnes River in Eldorado County, is credited with the idea of causing the stems to rotate somewhat between each drop so that the heads would wear relatively evenly. This seemingly minor adjustment in the way a stamp mill functioned paid great dividends to mill operators, because it greatly reduced the amount of time operations had to be interrupted to repair worn heads. Self-rotating stamps were the central distinguishing characteristic of the California stamp mill. Other improvements came along, many not attributed to any one miner or mechanic by name. Mill operators and equipment manufacturer experimented with the shapes of cams and tappets, with the number of stamps in a battery, with weight of the stamps and the rate at which they dropped. Each improvement added materially to the efficacy of the California stamp mill.[50]

By 1898, when the Standard mill standing in Bodie today was built, California stamp mills had become fairly standardized. Batteries typically had five stamps each. Stamps weighed 1,000-1,400 pounds and dropped about 100 times per minute. The drop was 4-12 inches. The mortar box was a large rectangular vessel of cast iron, typically about a foot wide and five feet long and sitting on a stout foundation of concrete or masonry. Blocks of wood or a layer of rubber sat between the mortar and the foundation to cushion the blows of the stamps somewhat. The mortar was fitted with five replaceable dies set in a row along the bottom, one directly under each stamp. Along the backside of the mortar box was a slot, running nearly the entire length of the mortar, through which the ore was delivered. Along the front of the mortar was a larger opening fitted with a screen consisting of either woven wire mesh or a slotted or punched plate. When ore had been pulverized finely enough, it could pass through the screen. Operators used screens of varying fineness depending on the type of ore and the particle size to which it had to be crushed to expose the gold. A braced, wooden frame held the camshaft and stamps in place directly over the mortar. Each stamp consisted of four parts: 1) a steel or wrought iron stem 10-

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[49] William P. Blake, "The Blake Stone- and Ore-Breaker: Its Invention, Forms and Modifications, and It Importance in Engineering Industries," *Transactions of the AIME* 33 (1903): 988-1031; Bailey, *Supplying the Mining World*, 69-70.

[50] Courtenay De Kalb, "The California Stamp-Mill," *M&SP* 100 (21 May 1910): 736-738; C.P. Stanford, "Origin of the California Stamp," *Mining & Scientific Press* 76 (29 January 1898) 107; Paul, "Beginning of Quartz Mining in California," 108; Louis, *A Handbook of Gold Milling*, 109; Egleston, *The Metallurgy of Silver, Gold, and Mercury in the United States*, Vol. I, 152-154.

18 feet long and 2.5-4 inches in diameter and weighing 400-600 pounds; 2) a cast steel or iron tappet attached just above the mid-point of the stem and weighing 120-200 pounds; 3) a cast steel or iron head 16-20 inches tall, 8-10 inches in diameter, attached to the bottom end of the stem, and weighing 250-400 pounds, and 4) a replaceable cast or forged steel shoe, sometimes alloyed with chrome or manganese, having the same diameter as the head, weighing 150-280

pounds, and attached by a shank to the bottom side of the head. Shoes and dies were the parts of a stamp mill that had to be replaced most often due to wear caused by the ore being crushed.[51]

The cam shaft usually ran along the front side of a row of cams, because in most mills such positioning afforded more room for taking the cam shaft out to repair or replace cams. The cams were spaced along the shaft so that each cam was to one side of its respective stamp stem. A cam lifted its stamp by moving against the bottom surface of the tappet. Cams typically had two arms, each with a curved wearing surface, the curve being the involute of a circle of radius equal to the distance between the axis of the stamp stem and the cam shaft. Such a curve insured that the lift provided by the cam was always vertical and that the surface of the cam coming in contact with the tappet was always horizontal. Yet because the stems were round and were not keyed to the guides, the friction of the cam moving against the tappet would cause the stamp to rotate somewhat with each lift. This was the key to maintaining relatively uniform wear on the working face of the shoes and dies. A cam shaft lifted all five stamps in a battery, so the arrangement of the cams on the shaft was important to insure that the stamps dropped in the correct order. Mill operators had learned from experience that it was usually preferable that no neighboring stamps should drop in succession, so a typical stamp dropping pattern might be 1, 4, 2, 5, 3. If two batteries were arranged end to end, then a single cam shaft could lift ten stamps. Typically a single camshaft did not lift stamps for more than two batteries.[52]

Not surprisingly, an occupational hazard of working in a stamp mill was loss of hearing. H.W. MacFarren said in 1910:

> There is a serious part of stamp-milling--the loss of hearing. A 10 or 20-stamp mill is not hard on the hearing, but the larger mills cause the majority of men to become deaf in time. To save the ear drums as much as possible and reduce the distress of the continuous noise, wads of cotton, wool, or waste are worn in the ears. These should be softened with clean oil such as olive oil or vaseline, that they may not inflame the ears. Further relief can be obtained by sealing the ears up, after the cotton, with a soft pliable wax or stiff salve that can be moulded into

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[51] "A Model California Stamp Mill," *M&SP* 76 (29 January 1898): cover page; Louis, *The Dressing of Minerals*, 164-170; Rickard, *The Stamp Milling of Gold Ores*, 205-215.

[52] Louis, *The Dressing of Minerals*, 170-172.

place.[53]

In early years of the California stamp mill, millworkers fed the batteries with ore by hand. The feeder had to judge by sight and sound whether he was feeding enough ore to the batteries.
Too little ore would allow the shoes to strike the dies. Too much ore would cause the stamps not

to fully drop the desired distance and would cushion the blow. About two inches of ore between the shoe and the die after each stroke was generally considered the ideal. Experts considered manual ore-feeding to be more effective than early automatic feeders, because the machines could not respond to the need of the battery for more or less ore. C.P. Stanford was one of the first to invent an automatic feeder that was satisfactorily responsive. Patented in 1858, it featured a moveable spout that was activated by means of a rod attached to a lever mounted near the tappet of the middle stamp. If the mortar box had enough ore in it, the tappet would not drop far enough to move the lever. If the mortar box was wanting ore, the tappet would drop far enough to hit the lever, which in turn would jolt the spout, thereby shaking some ore into the mortar. A San Francisco machinist named Joshua Hendy patented an automatic ore feeder in 1874 that also depended on a lever actuated by the tappet to regulate the flow of ore into the battery. Called the Challenge feeder, it differed from the Stanford feeder in that a rotating disc moved the ore from the hopper to the battery. The action of the lever determined the speed at which the disc rotated and fed ore. The improved ore feeders could deliver 15-20% more ore to the battery during the course of a day than a man could. Although several other types of automatic ore feeders were also patented in the 1870s and 1880s, the Challenge became nearly universally used in California stamp mills.[54]

In the earliest stamp mills, miners used mechanical means to capture small bits of gold. The crudest tools were a wool blanket or an animal hide with the hair or wool still on it. An operator would place the fabric in a trough and allow the pulverized ore to pass over it. Small pieces of gold would be trapped in the blanket or animal hair, which was then thoroughly washed periodically to recover the gold. Even in early quartz mills that employed amalgamation, blankets or hides were also used to collect gold in sulphuretes that would not amalgamate with mercury. Operators of early mills also used sluices with ripples to recover gold not recovered by amalgamation. These mechanical means were considered concentrators in a period before effective mechanized concentrators were available in California. Miners knew from their placering experience that mercury was the most reliable material for collecting free-

[53] MacFarren, *Practical Stamp Milling and Amalgamation*, 158-159.

[54] Stanford, "Origin of the California Stamp," 107-108; Egleston, *The Metallurgy of Silver, Gold, and Mercury in the U.S.*, Vol. I, 181-183; John Hays Hammond, "The Milling of Gold Ores in California," *Eighth Annual Report of the State Mineralogist for the Year Ending December 1, 1888* (Sacramento: State Printing, 1889), 699-703; Edward B. Preston, *California Stamp Mill Practices*, California State Mining Bureau Bulletin No. 6 (Sacramento: State Printing, 1895), 16-17; Bailey, *Supplying the Mining World*, 106-110.

milling gold by amalgamation, but it remained for them to devise effective methods for using mercury. During the first ten years of quartz mining in California, three techniques predominated: 1) amalgamating in the battery by adding mercury as the ore was being crushed and allowing the amalgam to settle into the bottom of the mortar; 2) allowing the pulp to flow from the mortar across an amalgamating plate, usually consisting of a sheet of copper coated with mercury; and
3) placing the pulp, ground by the stamps, into an arrastra, a Chile mill, or one of the various types of mechanical pans that evolved from those two Spanish devices. There was no uniformity in the methods and sequences of methods employed at California mills during the early years. Moreover, miners knew that if there were sulphuretes present in their ore, amalgamation was relatively ineffective at recovering much of the gold, so operators took care to store their tailings on dumps for future re-treatment.[55]

In addition to mercury, miners experimented with a variety of chemicals in an effort to modify the minerals in the ore to make the gold more amenable to amalgamation. Such experiments were even more numerous among the silver mines of Nevada, where silver was actually often locked with other elements in chemical compounds.[56]

Whether mill operators conducted some amalgamation inside the stamp batteries or all of it outside (on plates and in amalgamating pans), they had to stop the works from time to time to "clean-up," which meant to collect the amalgam so that it could be retorted. Typically, the amalgam was not clean, having some finely crushed pulp mixed with it. Prior to sending the amalgam to the retort, it was worked for several hours in an arrastra (in the early days) or a clean-up pan, which was an iron tub with vertical or near-vertical sides. The bottom of the pan was usually flat, and its grinding surface usually consisted of replaceable iron dies. Atop the dies sat a rotating iron disc, called a muller. Iron shoes were affixed to the underside of the muller. The grinding action of the shoes and dies polished unamalgamated particles of gold, making them susceptible for amalgamation, and freed the pulp from the amalgam. The amalgam would settle to the bottom while water added to the pan would wash the pulp from it. Amalgamating pans were similar to clean-up pans, but they were usually larger and they worked the ground ore for longer periods. Amalgamating pans were intended to grind or polish particles of gold in the ore or concentrates that had not been caught on the amalgamating plates earlier in the process. Sometimes chemicals were added as well to try to enhance the ability of the mercury in the pan to amalgamate with the precious metals.[57]

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[55] Hittell, *Mining in the Pacific States*, 158-166; Guido Kustel, *Nevada and California Processes of Silver and Gold Extraction* (San Francisco: Frank D. Carlton, 1863), 59-63; Eissler, *The Metallurgy of Gold*, 112-131; C.G. Warnford Lock, *Gold Milling Principles and Practice* (New York: Spon & Chamberlain, 1901), 225-242.

[56] M. Eissler, *The Metallurgy of Silver: A Practical Treatise* (London: Crosby Lockwood and Son, 1889), 62-82.

[57] Eissler, *The Metallurgy of Gold*, 131-139, 150-153; Lock, *Gold Milling Principles and Practice*, 247-265; Rose, *The Metallurgy of Gold*, Fifth Edition, 135-140, 164-170; Eliot Lord, *Comstock Mining and Miners*,

Concentrators are devices that mechanically separated mineral particles of greater density, which contained metals (including gold), from minerals of lesser density, which were considered to be of no economic value. The simplest form of concentrators were called settling boxes. Built of wood, they might be six feet wide and twelve feet long, with sides that sloped inward toward a discharge point. A slurry of pulp flowed into the box at the top of one end, and the water passed through the box to the other end. The width of the box, however, slowed the

velocity of the water to a degree that allowed the heavier fine solids to settle to the bottom, where they discharged into a launder that conveyed them to an amalgamating pan or similar device. Thus, by the time the water overflowed the discharge end of the box, it had rid itself of the heavier suspended solids. The metallurgical industry also had a long history of using devices like sluices that entailed passing a stream of water and pulp in suspension along a nearly horizontal surface to effect a separation of materials. From Cornish practice, these were often called "buddles." More elaborate buddles were circular, revolving tables with either horizontal, conical, concave, or convex surfaces. Pulp flowed onto the circular buddle near the center (except with the concave buddle), and, as table rotated, materials of different densities were carried by the flow of water to the perimeter at different rates. In the case of concave buddles, materials flowed onto the perimeter of the revolving table and moved toward the center at different rates.[58]

During the last quarter of the nineteenth century, innovators devised improved concentrating tables that employed moving, continuous belts and a reciprocating, shaking, or jerking motion to facilitate the separation of streams of particles in pulp. Such devices were called vanners. Sometimes the speed and amplitude of the reciprocating motion was the same in both directions, yielding a simple shake; sometimes there was a significant difference between the two, yielding a noticeable jerk in one direction. Sometimes the reciprocating motion was longitudinal and sometimes transverse. One of the earliest vanners was invented by William B. Frue. The Frue vanner used a continuous rubber belt, four feet wide, placed on rollers to form a flat surface about twelve feet long and with an incline of three to six inches along that length. The belt had rubber flanges along its edges to prevent pulp from overflowing the sides. In operation, pulp, evenly distributed across the entire width of the vanner, flowed onto the belt near the upper end. The belt moved slowly in an upward direction. Transverse shaking of the belt kept the less dense particles in suspension, while the gold and sulphuretes settled onto the belt. Those minerals would be carried by the belt over the roller at the upper end of the vanner, while the water flowing downhill carried the gangue off the lower end of the vanner. The Silver

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Monographs of the U.S. Geological Survey, Vol IV (Washington, DC: Government Printing Office, 1883), 80-88.

[58] Walter McDermott and P.W. Duffield, *Losses in Gold Amalgamation: With Notes on the Concentration of Gold and Silver Ores* (New York: E. & F.N. Spon, 1890), 53-63, plates II and III; Preston, *California Stamp Mill Practices*, 52-55; Eissler, *The Metallurgy of Gold*, 231-246; Lock, *Gold Milling Principles and Practice* 316-347; Rose, *The Metallurgy of Gold*, Fifth Edition, 172-174; Louis, *The Dressing of Minerals*, 293-336.

Hill custom mill is said to have installed Bodie's first Frue vanners in 1881.[59]

Gold and silver collected by concentrators had already failed to amalgamate with mercury on the aprons, so operators knew that some other method was necessary to recover the precious metals. Some concentrates were worked in amalgamating pans with various chemicals intended to alter the behavior of the pulp so that the precious metals would amalgamate with the mercury. Sometimes acid or alkali were added to change the pH of the pulp. Another typical pair of chemicals was common salt (NaCl) and copper sulfate (often called bluestone). Use of these chemicals in an amalgamating pan was called the Washoe process, which was developed in Nevada. Almarin B. Paul, an early stamp-millman from California, is usually credited with developing the Washoe process on the Comstock Lode. He combined the idea of a mechanize iron pan that improved on the arrastra (an idea of Israel Knox and Henry Breevort, two other Californians working on the Comstock), with the chemicals used in the Mexican patio process. He used steam to heat the contents of the pan and facilitate the chemical reactions. Although more typically used in silver mills, the Washoe process was also used in some gold mills to recover silver or electrum not collected on the aprons. Other concentrates were sent to chlorinating vats (after first having roasted the concentrates) for gold recovery. Chlorination employed heat and chemicals to dissolve the gold and produce a solution of gold chloride. Gold was then precipitated out of solution using another chemical such as ferrous sulfate. If a mill did not have its own chlorination plant, it might send its concentrates to a company that did.[60]

The cyanide process proved to be the greatest advance in nineteenth-century treatment of gold ores. Since the late 18th century, chemists and metallurgists had known that gold was soluble in potassium cyanide (KCN, an atom of potassium combined with the univalent radical of an atom of carbon and an atom of nitrogen). For more than forty years, experimenters in Europe and North America had tried to develop a practical process for using that property to recover gold from complex ores, but not until 1886 did any achieve practical success. That year, metallurgical chemist John Stuart MacArthur and the Forrest brothers (R.W. and William, both medical doctors) of Glasgow, Scotland, devised a commercially practical process by which they dissolved gold and silver from crushed ores using a weak solution of cyanide and then precipitated the precious metals by introducing zinc shavings. Especially important was their

[59] Rose, *The Metallurgy of Gold*, Second Edition, 166-183; Rose, *The Metallurgy of Gold*, Fifth Edition, 178-184; Louis, *The Dressing of Minerals*, 337-345; Egleston, *The Metallurgy of Silver, Gold, and Mercury*, Vol II, 495-514; Adams, *Hints on Amalgamation and the General Care of Gold Mills*, 30-34; Young, *Western Mining*, 139; Wedertz, *Bodie, 1859-1900*, 187.

[60] Eissler, *The Metallurgy of Silver: A Practical Treatise*, 31-37; Rose, *The Metallurgy of Gold*, Fifth Edition, 239-284; Grant H. Smith, *The History of the Comstock Lode, 1850-1920*, Geology and Mining Series No. 37, University of Nevada Bulletin 37 (July 1943): 41-43; A.D. Hodges, "The Washoe Process," *M&SP* 100 (21 May 1910): 757. Paul's claim to have developed the Washoe pan process was disputed, as were so many claims for developments of this sort; see the series of letters to the editor in *Mining and Scientific Press* 18 (13 March 1869): 169, (20 March 1869): 178, (27 March 1869): 194, and (3 April 1869): 210.

discovery that, by adding lime, caustic soda, ammonia, or other chemicals to the pulp or ores containing the sulfides of other metals, cyanide could dissolve gold in the presence of the sulphuretes that had so frustrated miners for decades. The following year, the trio formed a business syndicate, patented their Forrest-MacArthur process, and its use spread quickly to New Zealand, South Africa, and Australia, and less quickly to the U.S. The world's first application of the cyanide process was at the Crown mine at Karangahake, New Zealand, in 1889. The first in the U.S. was at the Mercur mine in Utah in 1891.[61]

Chapter Five: The Standard Consolidated Mining Company

An important mining property to change hands during Bodie's dull years in the 1860s and early 1870s was the Bunker Hill-Bullion set of claims. O.G. Leach, E. Donahue, and L.H. Dearborn staked the Bunker Hill claim in July 1861. In 1874, the property was in the hands of William O'Hara, an African-American who lived in Aurora. That year, he leased and then sold the Bunker Hill-Bullion to Peter Eshington and Louis Lockberg for $8,000. They drove a shaft 120 feet into Bodie Bluff and found a rich orebody. Crushing their ore in an arrastra on Rough Creek five miles to the northwest, they were able to produce $37,000 worth of gold in two seasons. With that showing, George Story bonded the property for Daniel and Seth Cook of San Francisco, who bought the Bunker Hill-Bullion in September 1876 for $67,000. The Cooks then incorporated the Standard Gold Mining Company on 11 April 1877 with Daniel Cook as president, John F. Boyd as vice president, William Willis as secretary, and the Nevada Bank of San Francisco as treasurer. William Irwin was the company's superintendent. During the first year of operation, the Standard sent its ore to the Syndicate mill (the old Empire mill) for treatment. The Standard's ore was so rich that within a year the company had paid its costs and was returning rich dividends to its investors. In the wake of the Standard success, several other companies incorporated to capitalize mine development at Bodie. Some of those companies were related to the Standard. Daniel Cook was also president of the Bulwer Mining Company, incorporated 20 June 1877. William Irwin was also superintendent at the Bulwer as well as the Bodie and the Summit mining companies, incorporated later that year.[62]

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[61] Alan L. Lougheed, "The Discovery, Development, and Diffusion of New Technology: The Cyanide Process for the Extraction of Gold, 1887-1914," *Prometheus* 7 (June 1989): 61-74; Rose, *The Metallurgy of Gold*, Fifth Edition, 248-249, 345; H.W. MacFarren, *Text Book of Cyanide Practice* (New York: McGraw-Hill Book Company, 1912), 1-3, 21-27; Roger P. Lescohier, *The Cyanide Plant: More Gold from the Same Ore* (Grass Valley, CA: Empire Mine Park Association, 1992), 13-18; Roger Burt, "Innovation or Imitation?", 334-335. Note, sometimes the Cyanogen radical is abbreviated "Cy," so in some texts potassium cyanide is given as KCy; see MacFarren, *Text Book of Cyanide Practice*, 7. Note also that sodium cyanide (NaCN) has nearly the same properties as potassium cyanide, especially regarding the dissolving of gold and silver. Both NaCN and KCN were used in metallurgical plants; see MacFarren, 9-10.

[62] Wasson, *Bodie and Esmeralda*, 6, 9-10, 25-28; Wedertz, *Bodie, 1859-1900*, 131; Whiting, "Mono County," 383.

Having proved the value of its ore at the Syndicate mill, the Standard Company decided in 1878 to build its own mill at the base of the hill on the east side of town. The mill housed twenty stamps, blanket sluices, a series of twenty settlers, sixteen pans, and two agitators. An aerial tramway delivered ore to the mill from the company's shaft near the top of High Peak. Earnings from the Standard's ore treated at the Syndicate mill paid the entire cost of the new mill and tramway. Stamping Standard ore produced considerable slimes, so the company installed the system of settlers to precipitate as much of the fine solids as practicable. After the stamps crushed the ore, the pulp ran into the first row of settlers, where some of the solids settled out.

Overflow from that group of settlers flowed into a second row of settlers, where more solids precipitated to the bottom. Overflow from those settlers was pumped to the third and last row of settlers, each more than twice as long as those of the previous two rows. Overflow from the last group of settlers was pumped to a tank over the stamp batteries to be reused in crushing fresh ore. Water for milling came from a spring a half-mile distant. By recycling water, the Standard conserved a resource that was scarce at Bodie's high elevation. Pulp from the settlers was charged to the amalgamating pans, where workers added mercury for the recovery of gold. The company sent tailings washed from the pans to impoundments west of the mill along the east side of Bodie Creek.[63]

The Standard mill was steam-powered. As was typical of other Bodie mills, much of the Standard mill's equipment came from other camps. The two boilers came from the hoisting works of the Florida mine at Virginia City, Nevada. The Corliss steam engine had previously been used at the Del Monte mill at Aurora. In addition to driving the stamps, the steam engine provided power for the Standard mill's machine shop, located next to the engine room on the south side of the mill.[64]

On 7 February 1979, the Standard Consolidated Mining Company incorporated. Six days later the old Standard Gold Mining Company deeded all its property to the new Standard Consolidated and then dissolved as a corporate entity. The new corporation paid the old company's eighteenth dividend and assumed liability for all of its outstanding bank drafts. The Standard Consolidated Mining Company had the same slate of officers as the Standard Gold Mining Company.[65]

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[63] Wasson, *Bodie and Esmeralda*, 28-30; Wedertz, *Bodie, 1859-1900*, 181-183; Eysen, "Map of Bodie Mining District," 1880.

[64] Wasson, *Bodie and Esmeralda*, 28; Wedertz, *Bodie, 1859-1900*, 182.

[65] *First Annual Report of the Standard Consolidated Mining Company for the Year Ending February 1, 1880* (San Francisco: Bunker & Hiester, Printers, 1880), frontispiece, 34.

When the Standard mill was operating around the clock, men in the engine room apparently worked twelve-hour shifts, as was typical at the time, but the men in the mill itself may have worked eight-hour shifts.[66] Payroll records for the early 1880s show that the highest-paid man in the mill was the chief engineer, and there were two of them who worked 31 days each month at $6.00/day. There were also two other engineers who each worked 31 days per month at $4.00/day as well as two firemen who each worked 31 days per month at $4.00/day. In the mill proper, however, there were three men feeding the batteries, three amalgamators, three assistant amalgamators, and three men working the settling tanks, each of whom worked every day of the month and was paid $4.00/day. Presumably their shifts were staggered throughout the 24-hour day. Others who worked virtually every day of the month, but presumably only during day shift, were an assistant assayer ($5.00/day), a blacksmith ($5.00/day) and a blacksmith's helper ($4.00/day), a carpenter ($5.00/day), a man on the woodpile ($3.50/day), a man on the ore dump ($4.00/day), a man working the aerial tramway ($3.50), an man or two working the settling tanks ($4.00/day), a stable hand ($4.00/day), and a laborer ($3.50). One or two watchmen ($4.00/day) also worked every day of the month, but they may have worked night shift. An additional stable hand or fireman occasionally worked about the place. On rare occasions, the company also hired masons ($7.00/day) and boilermakers ($5.00/day) to work on the boiler or elsewhere in the mill.[67]

As mentioned above in the review of mills built at Bodie during its boom, the Standard Company owned a share in the Standard-Bulwer mill in addition to owning the Standard mill outright. The Standard and the Bulwer companies each owned fifteen of the Standard-Bulwer's thirty stamps. During Bodie's doldrums of the late 1880s, the Standard's fifteen stamps were the only ones dropping in the entire camp. Even the Standard mill was closed for about five years in the late 1880s. The Standard-Bulwer had a different flow sheet than the Standard mill. At the Standard-Bulwer, pulp from the batteries was treated directly in twelve amalgamating pans, in which steam heated the pulp to 160^0 F. The only chemicals added to the pulp during amalgamation were soda and lime to keep the mercury clean. A later superintendent of the Standard mill thought it odd that in the 1880s the company used only amalgamating pans and not amalgamating plates at the Standard-Bulwer mill, because the free-milling nature of the Standard

[66] "It has become a custom almost universally established in mining centres, that mill-men work 12 hour shifts. This indeed they can easily do, as the labour is but light, except when anything goes wrong; then all hands have to work as hard as they well can in order that the least time possible may be lost." Louis, *A Handbook of Gold Milling*, 419-420.

[67] "Mill Payroll, 1879-1892," Records of the Standard Consolidated Mining Company, Record Group 36 (Linknum 1147), Bodie State Historic Park Archives (hereafter cited as BSHP), California State Archives, Sacramento. Henry Louis, *A Handbook of Gold Milling*, 419-411, described the typical crew at a stamp mill. The Standard mill had a larger crew than was typical for a twenty-stamp mill. This may have been due to the fact that the Standard mill relied on numerous settling tanks and amalgamating pans rather than the simpler system, employed after 1890 at the Standard, of amalgamating on plates. The reliance on settling tanks and amalgamating pans may also explain the apparent 8-hour shifts.

ore meant that simple plate amalgamation was the least expensive means of gold extraction.[68]

To pull the Standard Company out of its decline, the officers asked Arthur Macy to inspect the property in 1890 and make recommendations. Macy was an experienced mining engineer who had worked at Arizona's Silver King mine and elsewhere in the West. After his positive report, the Standard asked him to take charge of the operations. He agreed on condition that the company make $50,000 available to him for capital improvements. Although Macy spent most of that money making underground improvements, he did make a significant improvement to the Standard mill as well. During the summer of 1890, he installed two Frue vanners and showed that gravity concentration prior to amalgamation could help put the operation on an economical footing. He installed three more Frue vanners shortly thereafter.[69] Macy's hiring began a practice by the Standard Consolidated of employing skilled engineers to superintend the operation at Bodie. Such was not always the case at small western gold stamp mills, where companies often put men in charge who were noteworthy for their mechanical skills, not their understanding of metallurgical theory or practice.[70]

The Standard Company next hired Thomas Leggatt to superintend the mine and mill at Bodie. His two most important changes in improving the economics of the operation were: 1) to experiment with and then implement the cyanide process, and 2) to shift from steam to electrical power. Use of the cyanide process grew out of Leggatt's efforts to recover additional gold from the Standard mill's tailings. During the summer of 1892, he had an area of the Standard tailings dump plowed in an attempt to accelerate oxidation of minerals in the pulp. Then he had the tailings excavated and re-treated in amalgamating pans, yielding a very base bullion of only about 100 fine in gold and silver. Leggatt sent a sample of more than a ton of Standard tailings to the Denver laboratory of the Gold and Silver Extraction Company of America, Limited, the U.S. representative of the MacArthur-Forrest syndicate in Glasgow, Scotland. The results showed, he concluded, that gold recovered by the Forrest-MacArthur process would not pay for costs plus licensing fees. In 1893, Leggatt began corresponding with J.S.C. Wells, one of his old professors at the Columbia School of Mines, to find a means of leaching gold from Standard ore, concentrates, or tailings to improve the company's overall gold recovery rate. Leggatt sent samples to Wells to test in his Columbia laboratory using chlorination under pressure. The Standard Company also received letters that year from other companies using the cyanide process, including the Gold and Silver Extraction Company, which was still soliciting the Standard's business, and the Mechanical Gold Extraction Company of New York, which used

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[68] Whiting, "Mono County," 394; Robert Gilman Brown, "A Bodie Gold Stamp Mill," *E&MJ* 61 (27 July 1896): 615.

[69] De Groot, "Mono County," 337; "Thomas Leggatt: An Interview," in T.A. Rickard, *Interviews with Mining Engineers* (San Francisco: Mining and Scientific Press, 1922), 260.

[70] MacFarren, *Practical Stamp Milling and Amalgamation*, 148; Rickard, *The Stamp Milling of Gold Ores*, 216-225.

cyanide in a higher concentration than that recommended by the MacArthur-Forrest patent.[71]

While visiting San Francisco in 1893, Leggatt met Alexis Janin, who was running experiments on the cyanide process in a laboratory there with Charles W. Merrill, a recent graduate student of the University of California's College of Mining. A native of New Hampshire, Merrill grew up in Alameda, California, and would go on to be one of the nation's leading engineers of the cyanide process, known especially for his work at Marysville, Montana, and with the Homestake Mining Company in South Dakota. After Janin and Merrill reported 80-90% gold recovery on the sample Leggatt had sent them, he invited Merrill to Bodie to perform larger-scale tests on tailings from various areas of the Standard's tailings impoundments. Satisfied with the results, the company's officers authorized construction of a mill capable of treating 100 tons of Standard tailings daily using the cyanide process. Construction began in June 1894 and the plant began operating that September. Leggatt claimed it to be the first of that size on the West Coast.[72] The plant had several vats 20 feet in diameter. Each vat had a capacity of 80 tons of tailings. Leaching with cyanide and washing with water took as long as 40 hours per vat. The "liquor" that was drained from the vats and that held the gold in solution was then sent to zinc boxes, where the gold precipitated out as a slime, which had to be collected from the boxes and melted to yield bullion.[73]

A month after the Standard's cyanide plant started re-treating tailings, Merrill's analysis showed that costs of operation were less than $1.25/ton to extract gold and silver worth about $4.00/ton. By December 1894, the Standard's new cyanide plant had recovered $16,000 worth of gold and silver, a significant contribution to the company's total receipts of $259,790 for 1894. One drawback of the cyanide operation, however, was that the tailings impoundments froze in

[71] "Thomas Leggatt: An Interview," 261; J.S.C. Wells to Thomas Leggatt, letter dated 9 February, folder 001; Wells to Leggatt, letter dated 16 August 1893, folder 002; W.O. Ross to Standard Consolidated Mining Company, letter dated 26 May 1893, folder 003; and Gold and Silver Extraction Company of America to the Standard Consolidated Mining Company, letter dated 20 December 1893, folder 009, all in box 91, RG-36 (Linknum 1178), BSHP; "Mill-Work, Concentrates and Tailings at Bodie," *M&SP* 66 (24 June 1893): 386-387.

[72] "Thomas Leggatt: An Interview," 261; "Charles Washington Merrill," in Rockwell D. Hunt, ed., *California and Californians*, Vol. V (Chicago: The Lewis Publishing Company, 1926), 318. In his interview with Rickard, Leggatt recalled having sent a sample to Denver in 1892. It is worth noting that a late 1893 letter from the Gold and Silver Extraction Company of America to the Standard Consolidated Mining Company in the Bodie State Park Archives suggests that the Extraction Company was soliciting the Standard Company to send a sample so tests could be made; see Gold and Silver Extraction Company of America to the Standard Consolidated Mining Company, letter dated 20 December 1893, folder 009, box 91, RG-36 (Linknum 1178), BSHP.

Leggatt's claim for the Standard cyanide plant's primacy in California is substantiated by A. Scheidel, *The Cyanide Process: Its Practical Application and Economical Results*, California State Mining Bureau Bulletin No. 5 (Sacramento: State Printing, 1894),88-95.

[73] "Mono County," *Thirteenth Report of the State Mineralogist for the Two Years Ending September 15, 1896* (Sacramento: State Printing, 1896), 231.

cold weather, making it unfeasible to continue operations through the winter. By Christmas 1894, the Standard's profitable new cyanide plant was closed for the season. In 1895, of its total $197,106 in revenue, the Standard Company derived 40% ($78,937) from re-treating tailings in its cyanide plant. During the winter of 1896-97, the Standard began experimenting with a method for pumping tailings through a pipe directly from the stamp mill to the cyanide plant, hoping to obviate the need for winter closure. In 1896, the Standard Company also built a second cyanide plant down in Bodie Canyon, where natural topography had collected a sizeable deposit of tailings that flowed out of Bodie's mills. By that time, three other companies were operating cyanide plants as well. One of them was the Southend Cyanide plant, also called the Booker Flat plant, owned by J.S. Cain and others. It began operating in September 1895. By 1898, the cyanide plants at Bodie were treating about 15,000 tons of tailings each month.[74]

Leggatt's other major innovation was to use electricity to power the Standard's mining and milling operations at Bodie. As already noted, wood was very expensive at Bodie. By the time Leggatt arrived, the railroad linking the camp to Mono Mills was temporarily out of service. Firewood cost $11.00 per cord. During the first six months of 1891, the Standard burned 671 cords of wood (worth nearly $7,400) to fire its boilers at the mine and 1,873 cords of wood (worth more than $20,600) to fire the boilers at the mill. Looking for an alternative to firewood, Leggatt learned of L.L. Nunn's use of electricity in 1891 to power the San Miguel Gold Mining Company's operation at Telluride, Colorado, by transmitting electricity three miles from a hydroelectric generating plant to the mine. The project was said to have been the first "long-distance" alternating current transmission system in the U.S.[75] Concluding that electricity could greatly reduce costs for power at Bodie, Leggatt decided that a location along Green Creek, about twelve miles west-southwest of Bodie, would be the best place to build a hydroelectric generating plant. The Standard Company acquired a water right on Green Creek from T.B. Hickey. A tributary of the East Walker River, Green Creek flows out the Sierra Nevada with enough volume during the dry months to satisfy the Standard power requirements as Leggatt calculated them. His measurements taken while the steam engine powered the mill had shown

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[74] C.W. Merrill to T.H. Leggatt, letter dated 17 October 1894, folder 009, box 92, RG-36 (Linknum 1179), BSHP; *E&MJ* 58 (15 December 1894): 565; 59 (2 March 1895): 204; 61 (29 February 1896): 211, (4 April 1896): 332; *M&SP* 69 (22 December 1894): 394; 71 (21 September 1895): 186; 72 (18 January 1896): 50, (4 April 1896): 270; 73 (19 December 1896): 506; 77 (6 August 1898): 137.

[75] Report of through June 1891, in "Progress Reports of Manager Thomas H. Leggatt, June 1891 to December 1895," folder 6, box 94, RG-36, BSHP; Thomas Haight Leggatt, "Electric Power Transmission Plants and the Use of Electricity in Mining Operations," in *Twelfth Report of the State Mineralogist, Two Years Ending September 15, 1894* (Sacramento: State Printing, 1894), 438; Thomas Parke Hughes, *Networks of Power: Electrification in Western Society, 1880-1930* (Baltimore: Johns Hopkins University Press, 1983), 162. Note that in Leggatt's article he states that wood was $10.00 per cord, while the records of the Standard Company in the Bodie Archives show that, in 1891 at least, the company was paying $11.00 per cord.

that the mill needed an average of 90 horsepower and a maximum of 101.5 horsepower. He consulted with an electrical engineer in San Francisco named W.F.C. Hasson, who recommended that a single-phase synchronous system made by the Westinghouse Electric and Manufacturing Company would be the most economical for generating electricity on Green Creek and transmitting it to Bodie. According to Hasson, the Standard's electrical system at Bodie was the first installed in California strictly for the purpose of providing industrial power (as opposed to lighting).[76]

Construction began in the summer 1892 using materials from the defunct Standard-Bulwer mill for construction of the powerhouse on Green Creek. The Standard Consolidated Mining Company acquired and rehabilitated Hickey's old ditch for use at the Green Creek power plant. The ditch extended 4570 feet from the diversion on Green Creek to its lower end, where it delivered water through a 1,571-foot pipeline to the power plant under a 355-foot head. Four Pelton wheels drove the A.C. generator and D.C. exciter. The 3,000-volt transmission line consisted of wood poles carrying a pair of wires along an almost straight right-of-way between the power plant and Bodie, a distance of 12.46 miles. The company also built a fourteen-mile telephone line from Bodie to the power plant. The phone line was located more than a mile away from the transmission line to avoid interference with the telephone signal. At the Standard mill, the electricity delivered from Green Creek drove a 120-horsepower motor, which in turn powered the mill's equipment. When the conversion from steam to electrical power was made in 1893, the Standard mill housed a rock crusher, twenty 750-pound stamps, four Frue vanners, eight amalgamating pans, three settlers, an agitator, and a pan and settler used for treating concentrates, as well as a bucket-elevator, hoist, machine tools, and other equipment necessary for work around the mill. The drive-train for the mill included a friction clutch on the shaft between the electric motor and the main drive pulley. The Standard Company began testing its new electrical apparatus during the summer of 1893, revealing problems with the insulation around some of the electrical equipment at the mill. Westinghouse dispatched engineers to Bodie to remedy the situation.[77]

During the remainder of the year, the mill ran uninterrupted for several stretches, the

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[76] Leggatt, "Electric Power Transmission Plants and the Use of Electricity in Mining Operations," 419, 429; Leggatt, "A Twelve-Mile Transmission of Power by Electricity," *Transactions of the AIME* 24 (1895): 316-317, 329; "The Water and Electric Plant at Bodie," *M&SP* 66 (17 July 1893): 370; W.F.C. Hasson, "The Successful Application of Electricity to the Operation of Mines," *M&SP* 69 (1 December 1894): 341-342. A letter to *Mining and Scientific Press* in March 1899 claims that California's first electrical plant installed to deliver industrial power was at Big Bend on the Feather River in 1888; see A.K. Beatson to the Editor, letter dated 14 March 1899, *M&SP* 78 (25 March 1899): 318. According to Beatson, the electricity was intended to power pumps and derricks being used in mining the river bed, but the plant delivered unsatisfactory service and was disassembled in 1889.

[77] "The Water and Electric Plant at Bodie," *M&SP* 66 (17 June 1893): 370; *E&MJ* 54 (20 August 1892): 181, (29 October 1892): 420; 55 (13 May 1893): 439-440; Leggatt, "Electric Power Transmission Plants and the Use of Electricity in Mining Operations," 419-435; Leggatt, "A Twelve-Mile Transmission of Power by Electricity," 315-338; Robert Gilman Brown, "Additions to the Power-Plant of the Standard Consolidated Mining Company," *Transactions of the AIME* 26 (1897): 319.

longest of which was twenty days. With the onset of winter and a decrease in the volume of ore being treated, the mill began working only one shift per day, and the new electrical apparatus also successfully performed daily start-ups. According to Leggatt, the Standard Company spent $38,000 building the system. Using electrical power, the company reduced its cost of milling from $3.78/ton to $2.32/ton, yielding a savings in October 1893 of about $2,100.[78] During the summer of 1895, Thomas Leggatt resigned his position as superintendent of the Standard mine and mill and moved to South Africa to continue his career as a mining engineer. Robert G. Brown took Leggatt's position at Bodie. Before he left, Leggatt had initiated several other

improvements that would make the Standard's operation more economical, especially by extending electrical power to the mine as well. To insure the power plant's year-round service, the Standard Company began construction in autumn 1894 of a rock-filled, timber-crib dam about 42 feet high across Green Creek. Completed late in 1895, the dam provided a reservoir to enhance the supply of water during periods of low flow. To insure that water would flow to the power plant throughout the winter, the company abandoned the old ditch, which often froze in winter, and replaced the 1,571-foot pipeline, which led from the ditch to the power plant, with a 3,875-foot pipeline that ran directly from the dam to the power plant. California law required that the dam be equipped with a fish ladder, and the Standard Company included one in its design for the dam. By the time the improvements were complete in 1896, the company had converted to electric hoisting and pumping at the mine. The new D.C. motors in the mine powered a hoist and a pump. To convert the A.C. electricity received at the motor room of the mill to the D.C. electricity needed for the motors in the mine, the company installed a D.C. generator at the mill, driven by a second belt attached to the same A.C. motor that powered the mill. Uninsulated wires then transmitted the D.C. electricity about 1200 feet to an adit leading into the mine.[79]

With the improvements in the delivery of power to its mine and mill, and with the certainty that the cyanide process would bring longevity to its Bodie operation, Standard superintendent R.G. Brown made a few changes in the mill to gain more economical results. Following is a summary of Brown's description of the mill's processes published in an 1896 issue of *Engineering and Mining Journal*. Ore arrived at the mill in 1.25-ton cars drawn up an inclined ramp by means of a winding drum. The mill treated about 54 tons of ore daily running at full capacity. None of the ore contained sulphuretes, so the gold was readily free-milling and there was little to dampen the mercury's ability to amalgamate with the gold. The cars dumped the ore on grizzlies with a space between bars of 2.5 inches. Fine material went through the

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[78] Leggatt, "Electric Power Transmission Plants and the Use of Electricity in Mining Operations," 435; Leggatt, "A Twelve-Mile Transmission of Power by Electricity," 337; *E&MJ* 57 (14 April 1984): 344.

[79] Brown, "Additions to the Power-Plant of the Standard Consolidated Mining Company," 319-339; *M&SP* 69 (20 October 1894): 250, (22 December 1894): 394; 70 (19 January 1895): 42; 71 (7 December 1895): 374; *E&MJ* 60 (6 July 1895): 13, (13 July 1895): 35, (20 July 1895): 59.

grizzlies directly to the ore chutes behind the stamps. The grizzlies directed coarse material to a Blake rock breaker. Brown complained that space around the grizzlies and rock breaker was crowded. He also complained that the size of the crusher was inadequate for the amount of hard ore the Standard treated.[80]

Challenge feeders delivered ore from the chutes to the batteries. Crushed pulp from the batteries flowed along plates 9 feet 6 inches long. The pulp then flowed through sluices to the vanners. Brown did not consider the vanners to be a very important part of the process, so he did not try to maximize their effectiveness. The concentrates the vanners produced were relatively rich in iron oxide and did not give up their gold in the amalgamating pans very readily. During monthly clean-up, sands were removed from the batteries while the stamps were hung-up, and those battery sands were ground separately in an amalgamating pan. The coarse gold found in the semi-vitreous quartz tended to settle to the bottom of the mortars, rather than pass through the screens and onto the plates. Concentrates and amalgam scraped from the plates were treated separately in pans. The Standard Company used the Washoe process in its amalgamating pans. To a batch of 1200 pounds of battery sands, workers added 20 pounds of salt and 6 pounds of lye, grinding the stuff for 16 hours. Then they added quicksilver and ground the batch for another 4 hours before sending it to a settler. To a batch of 2000 pounds of concentrates, workers added 80 pounds of salt, 4 pounds of lye, and 14 pounds of bluestone, grinding the stuff for 12-14 hours. Then they added quicksilver and ground the batch for another 5 hours before sending it to a settler. The bullion produced from grinding the concentrates was fairly base, because of the iron content, and largely silver (only about 100 fine gold and 650-850 fine silver). Tailings were sent to the ponds, where water drained from the solids until they were thick enough to be excavated and re-treated in the cyanide plant.[81]

The Standard mill operated around the clock in 1896. According to Brown, the crew at the mill consisted of a foreman, a crusher-man (who also operated the hoist drawing ore cars into the mill), a battery-man, and a vanner-man during day shift, and a similar crew *sans* foreman during the night shift. In addition, the mill employed a machinist and helper, a carpenter, and as many as four motor-men to care for the electrical apparatus.[82]

Although Brown's 1896 description of the Standard mill is for the original building and

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[80] Brown, "A Bodie Gold Stamp Mill," 615.

[81] Brown, "A Bodie Gold Stamp Mill," 615-616; see also "Mill-Work, Concentrates and Tailings at Bodie," *M&SP* 66 (24 June 1893): 386.

[82] Brown, "A Bodie Gold Stamp Mill," 616. According to H.W. MacFarren, the crew at the Standard mill was generous. He suggested in 1910 that a shift consisting of a battery-man and a helper could run a mill of as many as forty stamps, handling all the tasks including amalgamation and concentration, but not repairs; see MacFarren, *Practical Stamp Milling and Amalgamation*, 152.

its operation, it is worthy of note for understanding the operation of the currently extant mill at Bodie. The original facility burned in 1898. The Standard Company rebuilt its mill immediately, stating that the new mill would be patterned largely on the old one.

In late 1896, officials of the Standard Consolidated Mining Company began negotiating with officials of the Bodie Consolidated, Bulwer Consolidated, and the Mono companies with the intent of merging. The merger was largely a formality, as the same interests generally owned most of the stock in the several corporations. Standard Consolidated acquired the property of those companies by January 1897. By May, Standard Consolidated had also acquired all the outstanding stock in those companies.[83]

Chapter Six: The Standard Mill

A. Early Years of the Present Standard Mill

In 1898, the Standard mill was twenty years old. In early October, the electrical system was shut down for repairs, and the mill's crew fired the boiler, which was still in place for just such exigencies. In the early-morning hours of the 5th, a fire broke out in the boiler room. Within a short time it spread through the entire mill, destroying it completely. Because the mill was insured, because the company had blocked out ample reserves in the mine, and because the methods being used in the old mill had been well adapted to the orebody in the Standard mine, the company decided to rebuild immediately using a similar milling scheme. All the equipment had to be replaced, however, because the intensity of the fire destroyed even the iron and steel parts. By November, construction of the new mill's structural frame was well underway, and corrugated iron sheathing for the building was in transit to Bodie. By late December, crews had enclosed the building, and mill equipment was beginning to arrive. While the new stamp mill was under construction, the Standard company closed its power plant at Green Creek to make improvements, but it continued treating tailings in its cyanide plant at Bodie. The new stamp mill was in operation by early February 1899.[84]

Due to gaps in the historical record, there is precious little information about the construction of the new Standard mill during the winter of 1898-99. For example, the Bodie Collection at the California State Archives in Sacramento includes extensive corporate records for the Standard Consolidated Mining Company for the 1880s and early 1890s, including

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[83] *E&MJ* 63 (2 January 1897): 30, (8 May 1897): 452, (5 June 1897): 589.

[84] Bridgeport *Chronicle-Union* 36 (8 October 1898): 3, (12 November 1898): 3, (24 December 1898): 3, (11 February 1898): 3; *M&SP* 77 (8 October 1898): 357, (17 December 1898): 611, (24 December 1898): 637; 78 (11 February 1899): 155; *E&MJ* 66 (8 October 1898): 435, (17 December 1898): 732, (31 December 1898): 795; 67 (11 February 1899): 190.

correspondence from and to Thomas Leggatt concerning the beginnings of using the cyanide process at Bodie. Unfortunately, the surviving records end about 1895. This may be the result of records lost during the San Francisco earthquake and fire in 1906. That spring, the Standard Consolidated had sent its annual report to the printer, but the report was destroyed by the fire following the earthquake before it could be published. All of the company's records at its San Francisco corporate office were likewise destroyed in the fire.[85] Several libraries and archives have fairly complete runs of Bodie newspapers during the boom years of the 1870s and 1880s, but no such complete run is known to exist for Bodie's principal newspaper during the 1890s, *The Miner*. The California State Library in Sacramento holds specimen copies of *The Miner*, but they are not for the dates of the fire or the reconstruction. Mono County's principal newspaper during the 1890s was the Bridgeport *Chronicle-Union*, and several libraries and archives hold complete runs. Unfortunately, the *Chronicle-Union* carried only a few brief notices describing the fire and the construction of the new mill.

The new Standard mill attracted less attention in the national mining press than the old mill had. This is perhaps due to the fact that the old mill was built at a time when the Bodie district was booming, so developments there would seem of more interest to readers of such journals as *Engineering and Mining Journal* and *Mining and Scientific Press*. Likewise developments like the electrification of the Standard mill and the adoption of the cyanide process in the early 1890s were pioneering efforts and so were worthy of note by a national readership. On the other hand, the new Standard mill was a conventional facility built in a district that promised no more excitement, just steady production for as long as the low-grade ore remained profitable.

The new Standard mill was built according to the plan of what had come to be considered "a modern California twenty-stamp mill."[86] The earliest known photographs of the mill, dating from about 1903, show that the mill had the conventional layout of a typical California stamp mill, much as it has today. Ore delivery and ore bins were located at the east or uphill-end of the

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[85] *Standard Consolidated Mining Company* (New York: Exchange Press, 1906), 3. Note that this report is not called an "annual report." It reproduces for the stockholders as many records as the company's officers could salvage from the mine office at Bodie, etc., but it does not follow the format of previous and subsequent annual reports, which summarized data for a given year collected at the corporate headquarters.

[86] The first page of an 1895 issue of *Mining and Scientific Press* provides and illustration and description of "A Modern California Stamp Mill," as built by the Joshua Hendy Machine Works. The item is about the mill at the Havilah mine at Nashville in El Dorado County, California, but four years later it could as easily have been about the new Standard mill at Bodie. The arrangement of levels, the location of equipment within levels, and the configuration of the mill building enclosing those levels are nearly identical to the new Standard mill, which was noticeably different from the original Standard mill, especially in the configuration and orientation of the roof; see *M&SP* 71 (21 September 1895): 175. Two years later, *Mining and Scientific Press* carried an illustration and description of "a model California stamp mill," as built by the Union Iron Works. It is virtually identical to the Hendy mill depicted in 1895; see "A Model California Stamp Mill," *M&SP* 76 (29 January 1898): 95.

mill, stamp batteries were located at the middle level, and vanners were located at the lowest level. The boiler room and machine shop were located along the south side of the mill, and the room that houses the amalgamating pans, which is an extension of the stamp-battery level to the north, was present from the beginning. The photographs also show that the ancillary buildings along the west end of the mill, including the small retort building and the small furnace building, were present then (but the north addition to the furnace building had not yet been built).[87]

The only significant change to the Standard mill building occurred in 1904-05, when the Standard Company installed a series of pumps for delivering tailings directly from the mill north to the cyanide plant. The change consists of a small bay added along the north side of the ore bins. The addition is visible in 1914 photographs, appearing to be a small dormer on the north side of the bins.[88] The Standard installed the pumps in conjunction with a new method of applying the cyanide process to tailings.

That the operation of the mill changed little because of the fire is evident in general manager R.G. Brown's report to the corporation on operations in 1900. He described the proportions of gold recovered from the products of the various means employed at the mill, including amalgam scraped from the plates, concentrates produced by the vanners, battery sands treated in the amalgamating pans, and tailings re-treated at the cyanide plants. He noted that, because the mine was producing less ore containing coarse gold than it had in previous years, the company was recovering less gold from the treatment of battery sands than had been the norm.[89]

The relatively high proportion of clay in the Standard ore continued to vex the cyanide operation, which required a slurry of a relatively higher proportion of solids than that which ran over the plates and vanners. After being run through the stamps, the clay was so fine that it took overly long to settle. It also resisted efforts at filtering, because even an eighth-inch coating of slime rendered a filter impervious. As a consequence, while the company continued to search for a more effective means to process tailings directly from the stamp mill, it continued to use its tailings impoundments as the most effective method of settling slimes. By directing tailings first to one cell and then to another, the company could allow virtually all the water to drain or evaporate from the tailings, leaving a caked bed of fine solids. Standard laborers could then excavate caked tailings from a cell that had fully settled. To facilitate handling in the cyanide plant, workers mixed sand with the slimes after they had been excavated.[90]

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[87] "Standard Mill, 1903," photograph 61, box 2, Photograph Archives, Bodie State Historic Park; photograph of the Standard mill, ca. 1903, copy provided to author by Michael Piatt, Holland, MA.

[88] Several copies of 1914 photos exist in the Photo Archives at Bodie; see photos 14 and 15, box 4; photo 15, box 8, and photo 82, box 11.

[89] *E&MJ* 71 (25 May 1901): 665.

[90] R. Gilman Brown, "Cyanide Practice with the Moore Filter--I," *M&SP* 93 (1 September 1906): 261.

In the summer of 1903, the Standard Company began experiments with the Moore filter process, after visiting a cyanide plant at Mercur, Utah, to witness the method in use. The Moore filter featured filter panels consisting of canvas stretched over perforated vacuum pipes. The filter panels could be lowered into a tank of tailings. Water drawn out through the vacuum pipes left a deposit of solids caked against the canvas filters. The panels were taken out of the tanks periodically and cleaned of solids. The Standard built a small experimental plant at Bodie that summer with a capacity to treat a half-ton of tailings per day. The tests were encouraging enough to merit rebuilding the cyanide plant a half-mile north of the stamp mill according to the newly devised flow sheet. Construction took place during summer 1904. After a year of fine-tuning, the Standard had its new cyanide plant running on a regular basis, treating all the stamp mill's tailings, to which the company added old tailings from the ponds, where excavation continued. Another new addition to the Standard's cyanide process was a tube mill, which the company used to further grind the coarser tailings from 30-mesh, produced by the stamp batteries (fitted with 30-mesh screens), to 200-mesh suitable for treatment in the cyanide vats.[91]

The new process also brought changes to the Standard's stamp mill. In conjunction with the introduction of the Moore filter process at the cyanide plant, the company began adding weak cyanide solution (rather than water) to the ore as it was being run through the stamp batteries. The operators also added lime to the ore before it was crushed. By adding cyanide to the slurry moving through the stamp mill, the company reduced the percentage of gold in the ore that it was able to recover on the amalgamating plates from about 64% to about 54%, but most of the gold not amalgamated would be recovered at the cyanide plant. Other operations in South Africa, New Zealand, and South Dakota that added the cyanide solution at the stamp batteries did so with the intend of sending the pulp directly to the cyanide plant, obviating the need for amalgamation. Evidently, the Standard's general manager R.G. Brown and mill superintendent Theodore Hoover chose to continue using its amalgamating plates because amalgamation was a superior way of collecting the coarse gold present in Standard ore. To reduce the amount of water in the pulp, however, the company increased the slope for the plates from 1.5 inches per foot to 2.5 inches per foot. With the installation of the new cyanide process, the Standard was able to achieve overall gold recovery of at least 90%.[92]

Despite sending tailings directly to the cyanide plant, the Standard also continued

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[91] Brown, "Cyanide Practice with the Moore Filter--I," 261-262; *E&MJ* 77 (23 June 1904): 1020; Walter W. Bradley, "Tube-Mill Lining," *M&SP* 94 (5 January 1907): 17; MacFarren, *Text Book of Cyanide Practice*, 137-142; Robert Peele, *Mining Engineers' Handbook* (New York: John Wiley & Sons, Inc., 1918), 1829; Arthur F. Taggart, *Handbook of Ore Dressing* (New York: John Wiley & Sons, Inc., 1927), 1015-1016.

[92] Brown, "Cyanide Practice with the Moore Filter--I," 261; Brown, "Cyanide Practice with the Moore Filter--II," *M&SP* (8 September 1906): 294-295; Rose, *The Metallurgy of Gold*, Second Edition, 325-326; Rose, *The Metallurgy of Gold*, Fifth Edition, 331.

concentrating the pulp on vanners as well. For some years, the company had used the Washoe process on concentrates, recovering a very base bullion in the process because of the high iron content (mostly iron oxide, but also some iron sulfide, or pyrite) in the concentrates. Treating concentrates by pan amalgamation had grown obsolete by the early twentieth century, with most companies sending their concentrates to a smelter or treating them by some kind of leaching, like the cyanide process. Once the Standard began adding cyanide to the ore as it was charged to the stamp batteries, the company altered the way it treated concentrates in the 5-foot-diameter pan as well. Concentrates continued to be treated in one-ton batches (see above), but bluestone was no longer added. Water was added to make the slurry in the pan about 45% solids (said to have the consistency of heavy cream). The batch was ground with 25 pounds of lime for 48 hours. Then cyanide solution and more lime were added. Grinding continued for another 24 hours, adding lime and cyanide as necessary to keep the alkalinity and the cyanide strength at desired levels. From there, the ground concentrates went to one of the larger settler pans for 24 hours of agitation. Then the pulp in the settler was diluted to the same percent of solids as the rest of the tailings and pumped to the flume, which conveyed the material to the cyanide plant for further treatment. Brown noted that the concentrates changed color during the process of grinding in the pans, from a dirty green to red-brown, due to oxidation of the minerals. The revised pan process increased the recovery of gold in the concentrates from 87% to 97% and the recovery of silver in the concentrates from 75% to 84%.[93]

The other change at the stamp will was the installation of a series of four Frenier pumps to lift the tailings 63 feet to an elevation sufficient to flume them to the cyanide plant 1800 feet distant. The flume was four inches wide and nine inches deep. Each of the lower three Frenier pumps had a lift of 16 feet 4 inches, and the upper-most had a lift of 14 feet. To accommodate the pumps, the Standard built the small addition on the north side of the ore bins mentioned above.[94]

The Frenier pumps were made by J.H. Frenier & Son of Rutland, Vermont. Each pump consists of a hollow steel drum with a horizontal axis. The drum is encased in a wooden box, which contained the pulp to be pumped. Thickness of the drum in Frenier pumps ranged from six to ten inches, and the diameter ranged from 44 inches to 54 inches. Inside the drum there is a steel plate spiral, like a clock spring, formed as follows: There is a single opening along the side of the drum. The steel plate forming the outside of the drum runs from the opening around the circumference, gradually decreasing in diameter so that when it reaches the opening there is a difference of about 2.5 inches. The plate extends to the interior of the drum, welded continuously to the ends of the drum. It continues in spiral fashion several times around until it approaches the hollow discharge shaft at the center. The result is actually a spiral tube of square

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[93] T.K. Rose, *The Metallurgy of Gold*, Sixth Edition (Philadelphia: J.B. Lippincott Company, 1915), 229; Brown, "A Bodie Gold Stamp Mill," 616; Brown, "Cyanide Practice with the Moore Filter--II," 295.

[94] Robert H. Richards, *Ore Dressing*, Vol. III (New York: McGraw-Hill Book Company, 1909): 1587-1589, 1594-1595.

section. Each time the drum revolves inside the box, it scoops some pulp into the spiral and then some air, forcing earlier-scooped material further into the spiral and finally out the hollow shaft at the center of drum. The pressure induced by forcing pulp into the spiral and the hydrostatic head developed inside the spiral is sufficient to force material out the center discharge shaft and up a pipe as much as 22 feet. A drum ten inches thick can pump as much as 5500 gallons per hour. The lifting force is not dependent on the speed at which the drum revolves but rather on the diameter of the drum and the number turns the spiral has within it. Frenier & Son recommended a speed of about 20 rpm. Centrifugal pumps lifting half that quantity a comparable distance may operate at over 600 rpm. Although easier to install and less apt to malfunction during intermittent operation, centrifugal pumps have a pulverizing effect on soft minerals. The Frenier pump operates well under constant conditions and performs best if the pulp is kept about seven inches below the discharge shaft.[95]

R.G. Brown was general manager of the Standard Company when it built the new cyanide plant in 1904 and installed the Frenier pumps at the stamp mill. Theodore Hoover was superintendent. Writing in *Mining and Scientific Press* about the Moore filter process, Brown also assessed the performance of the Frenier pumps in the stamp mill, saying:

> The Frenier pump, for a regular flow and for lifts within its capacity, is most satisfactory; the consumption of power is nominal and the wear is confined to the stuffing-box at the discharge; however, it requires more attention in operation, particularly in starting or stopping, and a great deal of pains in erecting.[96]

That the Frenier pumps are still in place suggests that they continued to provide satisfactory performance, despite the attention they required. Selection of the Frenier pumps had come after trying several other methods to elevate tailings from the stamp mill to the level of the flume running to the cyanide mill. The Standard Company first tried an air-lift, but when a section of the stamp mill sat idle, the decreased velocity of material flowing through the lift allowed the quartz sand in the pulp to settle back against the vertical delivery pipe and block it. A bucket elevator did not work in winter because quartz sand froze to the buckets. The company tried a centrifugal pump, but the wear on the runners was excessive, and consumption of power was much greater than the Standard was willing to tolerate. With the Frenier pumps, the company was able to lift 90,000 gallons of water and about 60 tons of solids daily.[97]

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[95] Richards, *Ore Dressing*, Vol. II, 870-871; Richards, *Ore Dressing*, Vol. III, 1588-1589; Peele, *Mining Engineers' Handbook*, 1703; Taggart, *Handbook of Ore Dressing*, 1107-1108; MacFarren, *Practical Stamp Milling and Amalgamation*, 159.

[96] Brown, "Cyanide Practice with the Moore Filter--I," 261.

[97] R. Gilman Brown to The Editor, letter dated 4 April 1904 and published in *M&SP* 77 (14 April 1904): 597-598; Edward K. Judd, ed., *The Mineral Industry During 1904* (New York: The Engineering and Mining Journal, 1905), 202-203; On the design, construction, and operation of an air-lift, see Taggart, *Handbook of Ore*

According to Brown, his company initially installed two Frenier pumps to lift the pulp 45 feet. That was sufficient for a flume that had a grade of 5/16-inch per foot. Experience showed, however, that such a gradual grade was insufficient to keep solids from settling along the bottom of the flume. Using two Frenier pumps for lifting material that far also exceeded the recommended maximum lift (22 feet) for each pump. Therefore, when the company rebuilt the flume to a grade of 7/16-inch per foot, it also installed two additional Frenier pumps, rather than just one, to gain the additional 18 feet of lift required.[98]

The value of tailings was evident in the efforts the Standard Company exerted to profitably recover gold from the tailings. It was also apparent to the Mono County Assessor and the Board of Supervisors. A dispute arose in 1907 between Standard manager A.C. Lassen and the County Assessor, who argued that the company's 100,000 tons of impounded tailings should be valued at one dollar per ton. The company claimed the tailings were worthless. Meeting as the Board of Equalization in July, the County Supervisors upheld the Assessor's position. From then through the close of 1912, when the supply of old tailings was nearly exhausted, the Standard Company re-treated more than 90,000 tons of material from the impoundments.[99]

In 1909, the Standard Company was growing fully aware that it was running out of ore. In an effort to maintain a supply of fresh ore, miners opened old workings at considerable cost to extract lower-grade ores that had been left behind in earlier years. Because of shortages of ore, the company was able to keep all twenty stamps dropping for less than 170 days out of the year. Despite signs that the Standard's successful run was nearing an end, the company converted from Moore filters to Butters filters at its cyanide plant in 1910. In the years following installation of the Moore system, the Moore Filter Company had won some litigation concerning infringement on its submerged vacuum filter patents. Nevertheless, the Butters Vacuum Filter Company continued to advertise its system, claiming it was operating under valid patents. It is not known to what extent either the litigious nature of the technology or actual operating factors influenced the switch from the Moore to the Butters process.[100]

In 1912, the Standard mill was one of only four stamp mills operating in Mono County.

Dressing, 1111-1117.

[98] Brown to The Editor, 4 April 1904 letter, 598; Brown, "Cyanide Practice with the Moore Filter--I," 261.

[99] *E&MJ* 84 (10 August 1907): 278; Arthur S. Eakle and R.P. McLaughlin, "Mono County," *Report 15 of the State Mineralogist* (Sacramento: California State Printing Office, 1919), 151.

[100] *M&SP* 100 (14 May 1910): 699; Eakle and McLaughlin, "Mono County," 154; U.S. Geological Survey, *Mineral Resources of the United States, Calendar Year 1911*, Part I--Metals (Washington, DC: Government Printing Office, 1912), 489; Arthur De Wint Foote, letter to The Editor dated 17 January 1908 and published in H. Foster Bain, ed., *More Recent Cyanide Practice* (San Francisco: Mining and Scientific Press, 1910), 112-113.

Its twenty stamps represented a large proportion of the 48 stamps dropping in the county that year. Mono County was a small factor, however, in California's total activity in 1912. The state had 190 stamp mills operating and 2,963 stamps dropping. There were another 293 inactive stamp mills with about 3,000 stamps hung-up. The 8,150 tons of ore treated at the Standard mill in 1912 still represented more than half the ore treated in Mono County, but it was a small fraction of the more than 2,000,000 tons of gold and silver ore treated in the state.[101]

The Standard Consolidated Mining Company continued mining ore, treating it at its stamp mill, and using cyanide to treat tailings from both the mill and the old ponds until late 1912. That winter, the company closed the stamp mill and cyanide plant and focused on exploring its mine workings for more ore. Enough was found to justify re-starting both plants in the spring of 1913. The supply of old tailings was exhausted in September 1913. During the last two month of tailings excavation, the work of scraping tailings from the ponds was turned over to leasers. By that time, there was only enough ore coming from the mine to operate the stamp mill at one-third capacity, which the company's management did not consider to be economical. After another month's work, the Standard's entire operation at Bodie closed in October 1913. During 37 years of mining and milling at Bodie, the Standard company had produced more than $16,000,000 in gold and silver and paid its investors more than $5,000,000 in dividends. The Standard property sat idle all of 1914, as the officers began negotiations with prospective leasers or buyers and some development work was conducted in the mine. Meanwhile, J.S. and Thomas Cain filed a complaint against the Standard company, alleging that since 1891 it had mined ore worth $700,000 from a claim they owned. After months of wrangling, J.S. Cain offered to dismiss his suit if the company would sell him its Standard properties at Bodie. In February 1915, sixteen months after the Standard mine and mill had closed, the company sold all its property at Bodie to Cain for $25,000. Later that year, he re-opened the mine to leasers and put both the stamp mill and cyanide plant in operation.[102]

From 1915 until the beginning of World War II, Bodie and Cain's Standard properties saw intermittent mining activities. During that period, Cain occasionally leased his properties to others, who tried their hand. In the late 1920s, the Alaska Treadwell Yukon Company and the

[101] *Mineral Resources of the United States, Calendar Year 1912*, Part I--Metals (Washington, DC: Government Printing Office, 1913), 585-602.

[102] *Thirty-Fourth Annual Report of the Standard Consolidated Mining Company for the Year Ended February 1913* (San Francisco: Gilmartin Company, Printers, 1913), 2-4, 11-12; *Thirty-Sixth Annual Report of the Standard Consolidated Mining Company for the Year Ended February 1915* (San Francisco: Gilmartin Company, Printers, 1915), 3-4; *Mineral Resources of the United States, Calendar Year 1913*, Part I--Metals (Washington, DC: Government Printing Office, 1914), 488; Eakle and McLaughlin, "Mono County," 150-151; Deed between Standard Consolidated Mining Company and J.S. Cain dated 23 February 1915, pp 537-542, Deed Book Y, Clerk and Recorder's Office, Mono County Courthouse, Bridgeport, CA.

Homestake Mining Company leased many of the defunct properties in the Bodie district, built a flotation mill, and tried to work some of the camp's lower-grade ores, with little success. During the early 1930s, there was little mining at Bodie because of the Great Depression. Bodie experienced a devastating fire in June 1932, which destroyed much of the business district. In the second half of the Depression decade, there was a small resurgence of mining activity. Nevertheless, in the years after 1915, Cain and all the other miners at Bodie were never able to equal or exceed in a single year the output in gold and silver that the Standard Consolidated Mining Company produced in 1912, its last full year of operation. All mining ended with the onset of World War II, when the federal government prohibited gold mining so that all the nation's mining efforts could be focused on metals needed for the war effort. The State of California acquired the property at Bodie, including the Standard mill, in 1962, and the town became a State Park.[103] Since then, Bodie and the Standard mill have been important components in the California State Parks' system, interpreting to thousands of visitors each year the industry that was a major lure to migrants moving to the California during much of the nineteenth century.

B. The Standard Mill Today

The Standard mill is a model late-nineteenth-century California stamp mill, built of heavy timber construction on stone foundation walls and sheathed in corrugated steel siding. The mill has several sections that, progressing from east to west, correspond with the stages in the processing of ore at the mill. The sections also step steeply downhill, so that gravity can facilitate the movement of material from one section to the next. The eastern-most (uphill) section houses the ore-receiving apparatus, the grizzlies, and the ore bins. It has a gable roof with ridge-line running north-south. The middle section, which houses the primary crusher, the batteries of stamps, and the amalgamating plates, has a simple shed roof sloping down to the west. The western-most (bottom) section, which houses the vanners, is likewise covered by a simple shed roof sloping to the west. There is a small north extension of the middle section, which houses the amalgamating pans. It has a shed roof sloping to the north. Three distinct rooms, each with its own gable roof, sit along the south side of the mill. From east to west, they are the electric motor room, the machine shop, and the boiler room. At the south end of the machine shop there is a small annex of recent construction. Although it, too, is sheathed in corrugated steel siding, it has battered side walls, distinguishing it from the original sections of the mill. Perimeter walls throughout the mill are pierced with window openings, filled with multiple-light sash.

The structure housing the grizzlies and the ore bins is built of wood planks and heavy timber supports. The space between the east supports of the ore bins and the east wall of the mill accommodates a multiple-flight set of stairs that gives access to the ore-receiving level above the

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[103] Ella M. Cain, *The Story of Bodie* (Sonora, CA: Mother Lode Press, 1956), 53-55; Loose, *Bodie Bonanza*, 212-215; Chesterman, et al, *Geology and Ore Deposits of the Bodie Mining District*, 32.

bins. Two trestles lead into the mill at this level. One approaches from the east and is horizontal, linking the mill with an ore-receiving station at the same elevation on the hillside. The other approaches from the north and features a steeply-inclined ramp. Both trestles are equipped with steel tracks for ore cars. The tracks leading from the eastern trestle sit atop those leading from the northern trestle, suggesting that the latter is original to the mill and that the former was built later. The incline accommodated cars trammed along the ground nearly 2,000 feet from a mine adit. An over-shot winding drum at the south end of the ore-receiving level served to draw ore cars up the trestle ramp and into the mill. Once in the mill, the cars could be side-dumped into one of two chutes along the east side of the tracks, which run nearly the full length of the level to the winding drum. Like other equipment in the mill, the winding drum was driven by a belt connected to an overhead lineshaft. The winding drum was manufactured by William Sellers & Company of Philadelphia. Being horizontal, the trestle from the east did not require a cable and winding drum or other mechanism to bring ore cars into the mill. Men could simply push a car into the ore-receiving level and dump the ore into a third chute situated over the southern-most grizzly.

Robert G. Brown's 1896 article in *Engineering and Mining Journal* on the operation of the original Standard mill described the operation of the system of delivering ore to the mill. As stated above, the Standard company re-built the mill in 1898, after the fire, largely on the pattern of the old one. Brown's description of the delivery of ore matches the arrangement of the incline, winding drum, and line shaft system presently in place, suggesting that this was one area in the mill where company saw little reason to change its practice:

> The ore arrives at the mill in cars of 1-1/4 tons, and is drawn up on an incline over the grizzlies. The maximum rise is 30' above the horizontal. For this a 3/4-in. wire rope is used, winding on a grooved worm-driven elevator drum. To this direct or reverse motion is imparted by straight and cross belts with intermediate operating pulley and outside idlers for "no motion." The slope is 100 ft. long and motion can be controlled from either end. The time of a round trip is 10 minutes, made up thus: up trip, 2-3/4 minutes; loading and dumping, 2 minutes; down trip, 2-3/4 minutes; shifting at bottom and connecting, 2-1/4 minutes.
>
> The cars being 6 ft. over all and solid on their trucks, with only a hanging door at one end, a simple dumping device, with a hard winch and tail rope, is arranged. Under the conditions of a small mill and the handling of less than 50 tons a day (or 40 cars), the device is allowable, but for a materially larger tonnage some more automatic device would be preferred, would indeed be necessary, were one man to handle the whole quantity and between times feed the crusher.[104]

[104] Brown, "A Bodie Gold Stamp Mill," 615.

The winding drum in the present Standard mill fits Brown's description. Mounted along the roof trusses are idler pulleys, which once carried the cable for controlling the movement of ore cars back down the incline. And at the base of the incline is a switch, suggesting that there were two sets of tracks along the ground, proving at least a siding so that cars returning to the adit could pass cars delivering ore to the mill.

Written in pencil on a white-washed knee-brace of the mill structure near the end of the tracks from the eastern trestle are three tables, each logging the number of cars and the number of tons of ore received monthly in one of the years 1902-1904. The numbers in the three tables are reproduced below. The Standard Consolidated Mining Company did not weigh the ore cars it received. Rather, it assumed from experience that each car delivered 1.25 tons of ore.[105] The tables verify the practice. For most months, the number of tons received is exactly 1.25 times the number of cars received. Because of the rough surface of the wood, some of the numbers are hard to decipher, which may explain the few instances in which the 5:4 ratio between tons received and cars received does not obtain.

Record of Ore Received at the Standard Mill, 1902-1904, As Recorded in Pencil on a Knee-Brace

	1902		1903		1904	
Jan.	1530	1912.5	1365	1706.25	1225	1531.25
Feb.	1376	1720	1254	1567	1222	1527.5
Mar.	1652	2065	1579	1972	1185	1481.25
Apr.	1720	2150	1558	1941	1225	1531.25
May	1614	2017.5	1482	1852.5	1354	1442
June	1546	1928.25	924	1155	1400	2005
July	1480	1850	1418	1753	1419	1773.75
Aug.	1565	1956.5	1421	1780	1289	1618.25
Sep.	1406	1757.5	1308	1631.25	1100	1375
Oct.	1535	1918.75	1138	1412.5	1450	1812.5
Nov.	1155	1815.75	874	1092	1105	1382.25
Dec.	1375	1712.5	83	100	1194	1497.5

[105] Whiting, "Mono County," 394. As Whiting reports, the Standard's practice of estimating the amount of ore carried in each car goes back to the 1880s, when he wrote, "The weight of ore, as in most instances throughout the quartz mills of this country, is not arrived at directly, but is estimated from the number of carloads. In the case of the Standard Mill, the carloads are credited with an average capacity of three thousand pounds of ore each--a figure arrived at as the average of many weighings of the loaded cars." Sometime between the 1880s and 1896, when R.G. Brown wrote his description of the Standard mill for *E&MJ*, the Standard either switched to smaller cars or changed its estimate for the amount of ore its cars carried to 1.25 tons.

Totals	22,804.25	17,962.5	18,977.5

The totals for each year are slightly greater than the total ore produced by the Standard Consolidated Mining Company each year as reported in *Report 15 of the State Mineralogist, 1915-1916*.[106] The differences likely represent the custom ores treated at the Standard mill those years.

The three ore chutes open onto three grizzlies below. The middle set of grizzly bars are missing. The remaining bars are 97 inches long, 5/8-inch thick, and 3 inches deep. Although several of the grizzly bars are slightly bent, making the spacing between them somewhat irregular, it averages about 2 inches. Ore that passed through the grizzlies would fall into the ore bins below. Pieces of ore that could not pass were shunted westward to a floor at the rock-breaker level. The rock-breaker is of the Blake jaw-crusher type. It has two fly wheels, each 24 inches in diameter. The jaws have a typical corrugated surface. Each jaw is about 18 inches wide and 25 inches deep. The primary crusher discharges into one of the ore bins below. The ore bins are built of wood planks with heavy timber supports.

The next level of the mill downward is the camshaft level, which is also at the level of the base of the ore bins. A floor runs between the ore bins and the batteries, giving workers access to the backside of the row of stamps. A walkway passes from along the south end of the ore bins past the south end of the stamp batteries out onto a floor in front of the stamps and directly over the amalgamating plates or aprons. The floor extends all the way to the west wall of the mill at this particular level, giving workers access to the front side of the row of stamps as well as to the main line shaft, which runs north and south along the west side of the level and at the elevation of the camshaft floor. The main drive wheel, 8 feet in diameter and 20 inches wide, is located at the south end of the main line shaft. A 19-inch leather drive belt linking the wheel to one in the engine room is still in place. Along the main line shaft, there are several other smaller wheels intended to drive equipment, including the stamps, but their belts are missing.

The twenty stamps of the Standard mill are configured, in typical fashion, in four batteries of five stamps each, with the four batteries standing in a row, north to south. The heavy timber-frame structure of the stamp batteries is of the front-knee configuration, meaning that the stout knee braces that provide lateral stability to the batteries extend from the front (west). The alternative, a back-knee configuration, would have braced the batteries at the back against the ore bins. Nearly all the components of the northern-most battery have been removed. The ten stamps of the two southern batteries were lifted by cams on a shaft driven by a pulley at its southern end. The ten stamps of the two northern batteries were lifted by cams on a shaft driven

[106] Arthur S. Eakle and R.P. McLaughlin, "Mono County," *Report 15 of the State Mineralogist* (Sacramento: California State Printing Office, 1919), 151.

by a pulley at its northern end. The pulleys are 75 inches in diameter and 17 inches wide. The belts linking the camshaft pulleys to the main lineshaft pulleys are no longer in place. The cams were cast by Fraser & Chalmers, a major mining and milling equipment manufacturer in Chicago. There are no cams on the north camshaft for lifting the stamps of the northern-most of the batteries. The cams are still in place for the second battery from the north, but it has no stamps in place. The camshafts are 6 inches in diameter, and there is about a 6-inch distance between the axis of the cam shaft and the axis of the stamps, stems of which are 4-1/4 inches in diameter. All the cams and all the stamps are place for the two southern batteries. The cams of the southern-most battery are set so that the stamps would drop in a 1, 5, 4, 2, 3 order. The cams for the third battery from the south (and the second battery from the north) are set so that the stamps would drop in a 5, 1, 4, 2, 3 order. Note that these orders deviate from the conventional nineteenth-century practice of not allowing adjoining stamps to drop consecutively.

The next level down is the stamp floor, which extends under the ore bins east of the stamp batteries and slopes down with the aprons west of the batteries. Each battery is equipped with a Hendy Challenge automatic ore feeder, which regulated the delivery of ore from the outlet of its adjacent bin. The Challenge feeder features a nearly-horizontal steel disk at the bottom of the hopper at the base of the bin. The disk is 29 inches in diameter and is tilted slightly toward

the mortar box. A rotating cog wheel beneath the disk engages cogs on the underside of disk, causing the disk in turn to revolve at the desired speed. The disk and cogs were driven as the stamps dropped by a lever that engaged a collar around the stem of the middle stamp. As the disk rotates, it conveys the desired amount of ore from the hopper into the backside of the mortar box.

The mortar boxes at the Standard mill were fabricated in 1908 at the Fulton Iron Works of San Francisco. The inside bottom dimensions of the mortars is about 14 inches by 52 inches. Five dies, each 9 inches in diameter, sit along the bottom or each mortar. The shoes attached to the bottoms of the stamp heads are also 9 inches in diameter. The screens attached to the front side of the second mortar box from the south is fitted with fine wire mesh and measure 10 inches by 55 inches. Pulverized ore would pass from the mortar boxes through the screens and onto the amalgamating aprons, which slope down and to the west, away from the batteries. The aprons are each about 4 feet wide and about 19 feet long. Each apron has three tiers, the tier closest to the batteries about 9 feet long and the other two each 5 feet long. There is about a 2-inch drop from one tier to the next. The purpose of the drop was to cause some mixing of the pulp as it flowed down the aprons, thus exposing more gold to the quicksilver coating.[107]

At the lower end of each apron is a rectangular wooden trough, called a cross launder.

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[107] Robert H. Richards, *A Text Book of Ore Dressing* (New York: McGraw-Hill Book Company, Inc., 1909), 107-108.

Each cross launder has a central discharge in the bottom leading to a steel cylinder or barrel, called a mercury trap or amalgam trap. There is an overflow pipe near the top of each trap which led to a set of launders leading to other parts of the mill. The cross launder collected the pulp flowing down the apron and sent it to the trap. In some mills, mercury sat in the bottom of the trap to afford one last chance to capture gold particles before the pulp went on to the next stage. In other mills, the trap served merely to capture bits of mercury or amalgam that may have worked loose from the aprons.[108] The launders downstream of the traps at the Standard mill could either send pulp to the vanner room at the west end of the mill or to the amalgamating room along the north side of the mill.

At the northwest corner of the battery floor, there is a small room, with its floor built out over the northern-most apron. Equipped with a small heating stove, the room gave the battery-man a place keep warm during winter months while keeping watch on the batteries and amalgamating plates.[109] Adjoining the battery-man's room on the north is another small enclosure, which may have been the mill foreman's office.

The large room that extends north of the battery floor may have been called the pan room. It houses three pans and the remains of what appears to have been a wooden settler box. The latter is located in the southeast quadrant of the room, and a clean-up pan (or amalgamating pan) is located in the northeast quadrant. Crude wooden steps lead from that level down to the west half of the room, where two more amalgamating pans or mechanical settlers are located at the lower level. The wooden settler and the clean-up pan each have a simple plank launder to convey material from a drain to the adjacent mechanical settlers. The clean-up pan is about 5 feet in diameter and about 38 inches deep. It is comprised of steel plate sides and has a central stem extending up above the top of pan. The central cone and muller are missing from the pan. The two mechanical settlers at the lower level are 8 feet in diameter and about 38 inches deep. The two pans also have the central stem, but unlike the clean-up pan, each settler also has its central cone and muller disc. None of the shoes or dies are in place, however. Atop the central stem are two hand wheels. The upper one is for turning the screw stem, which raised or lowered the muller. The lower hand wheel served as the jam nut to secure the cone and muller at the desired setting. The drive mechanisms for the pans are all located beneath the wood floor of the pan room. Extant cogs and axles suggest that there was once another amalgamating pan in the southeast quadrant where the settler box remains are now located.

Along the division between the battery floor and the room are two of the Frenier pumps. One is located just south of the settler pans and at a level lower than the amalgamating pans. It is also situated at an elevation low enough that tailings from the vanners (see below) could drain

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[108] Louis, *A Handbook of Gold Milling*, 291-293; Richards, *Ore Dressing*, 774; Taggart, *Handbook of Mineral Dressing*, **14**-18.

[109] MacFarren, *Practical Stamp Milling and Amalgamation*, 156.

to it. Pipes lead from this Frenier pump to the next one 18 feet higher and located just south of the clean-up pan and wooden settler. Pipes lead from that one to the next higher one, located in the small addition north of the ore bins, and pipes lead from that third Frenier to up to the fourth and last one, adjacent to the ore receiving level above the ore bins. Each Frenier pump has two pipes on its north side linking it to the next higher one. The pipe exiting the central shaft is the discharge pipe through which pulp was pumped to the next level. The other pipe is a return pipe, which served as an overflow for the next-higher box to regulate the pulp level and keep it 7 inches below the discharge pipe.

The Frenier pumps were used to pump tailings from the lower end of the Standard mill to a flume which ran from the north end of the ore receiving level to the cyanide mill, some 1800 feet to the north. The flume was supported on a trestle, which is visible in several historic photographs from the early 1900s.[110] One bent of the trestle is still affixed to the Standard mill above the incline that enters the ore receiving level from the north. A pipe and the wood debris of the other bents lie along the course of the flume on the hillside northeast of the mill, indicating that at some point the Standard company replaced the open flume with the pipe.

The vanner room runs along the west end of the mill. It is large enough to have once housed four vanners, but there are only two left in place. The two vanners represent a model called the Union vanner, a variation on the Frue vanner manufactured by the Union Iron Works of San Francisco. The shaking frame of a Union vanner is suspended by four threaded rods, each attached to one of the four steel legs of the vanner. The slope of the shaking frame, and thereby the belt, may be adjusted by turning hand screws atop each of the legs.[111] The boxes sitting under each vanner were used to collect concentrates that dropped off the belt after it rotated around the upper roller of the vanner.[112]

South of the battery floor is the boiler room. It houses a flywheel in the northwest corner. The wheel is 12 feet in diameter and 10 inches wide. The room also houses two boilers set in a brick mass. The boilers were made by H.J. Booth & Company, Builders, of San Francisco in 1874. Only the northern of the two boilers has a stack, which was fabricated by Prescott, Scott & Company in 1879. The foundation walls of the boiler room are of field stone, while those of the rest of the mill are of cut stone laid up in random ashlar. There is also a piece of charred timber set in the stone of the east foundation wall, leading to speculation that this was the boiler room of the original Standard mill. That may be the case, but photographic evidence shows that the boiler is not the original boiler in the old mill. A photograph of the ruins of the mill, taken shortly after the 1898 fire, shows that the old boiler sat on a north-south axis, while

[110] See, e.g., the panoramic view of Bodie from the hillside east of the Standard mill published in Arthur S. Eakle and R.P. McLaughlin, "Mono County," 150.

[111] Richards, *Ore Dressing*, Vol. II, 651.

[112] Richards, *Ore Dressing*, Vol. II, 646, 649.

present boiler is on an east-west axis.[113] The early dates on the present boiler are no doubt explained by the practice of taking pieces of equipment from other inoperative mills and transporting them to where they were needed.

East of the boiler room is the machine shop, housing several machine tools including a large and a small lathe, a drill press, and a small planer. All the machine tools were powered by overhead line shafts. At the north end of the machine shop is the main clutch for the Standard mill's entire system of line shafts, belts, and pulleys. The clutch is part of a shaft with a north-south axis. At the north end of the shaft is the wheel that was driven by a belt from the electric motor in the next room to the east. The belt is not in place. At the south end of the shaft is a wheel that is linked by belt to the large wheel at the south end of the main line shaft mounted at the west end of the camshaft floor. This belt is mounted in an operable position.

East of the machine shop is the electric motor room. It houses a General Electric induction motor rated at 440 volts and 40 horsepower mounted in a position to drive the wheel at the north end of the clutch shaft in the machine shop, described above. The motor room also houses three other large pieces of electrical apparatus including an A.C. motor, rated at 440 volts and 75 horsepower, and an A.C. motor/D.C. generator set. All of these pieces of equipment were manufactured by the Stanley Electric Manufacturing Company of Pittsfield, Massachusetts. The same company also produced some of the switches and other gear mounted on the walls and on the control panel in the southeast corner of the room. The A.C. motor/D.C. generator set probably served to provide electrical power for the D.C. motors in the mine, as described above. Although one source states that the Stanley Electric Company supplied the electrical equipment for the original installation at the old Standard mill, it is doubtful that the old equipment could have survived the 1898 fire. Moreover, in the old mill, D.C. power for the motors in the mine was generated by a D.C. generator driven by a belt from the main A.C. motor, not by an A.C/D.C. motor/generator set.[114]

There are several ancillary buildings near the mill that were not investigated in detail as part of this project. Northwest of the mill is a warehouse with a shed roof. It houses several banks of shelves stocked with a wide variety of supplies and replacement parts. Along the brow of an embankment above the former tailings impoundments west of the mill is a north-south row of small buildings that were closely associated with the operation of the mill. The northern-most building, just southwest of the warehouse, is a garage. South of the garage and west of the vanner room is the retort building. It houses a brick retort furnace with its horizontal, cylindrical

[113] Photograph of mill after the 1898 fire courtesy of Michael H. Piatt, Holland, MA.

[114] Leggatt states in, "A Twelve-Mile Transmission of Power by Electricity," 317, that the Standard Company let a contract for electrical apparatus with the Westinghouse Electric and Manufacturing Company. Billeb states, however, in *Mining Camp Days*, 153, that "the Stanley Electric Co..... furnished the equipment." Billeb provides no source for the statement.

retort in place, but not of the apparatus exterior to the furnace for condensing mercury survives. Between the retort building and the mill is a well, over which stands a small housing sheathed in corrugated siding and a timber structure similar to a headframe. South of the retort is a building the Park staff calls the smelter, built it two sections. The 1903 photograph of the mill shows that the origin portion of this building is the south section, which had an exterior chimney mass at the north end.[115] Evidence within the building suggests that, when the addition was built on the north, a brick furnace mass within the south section was demolished and a new furnace mass was built in the north section. It houses another horizontal, cylindrical retort, suggesting that this was a second retort building, not a smelter. The chimney serving the furnace may be the one visible in the 1903 photo prior to the addition. The timber framing of the original section of this building is heavier than that for the addition. South of the furnace building is a small electrical shop, housing shelves stocked with insulators and other electrical supplies.

South of the mill are several other buildings associated with it. Near the southwest corner of the mill and just east of the small electrical shop is the assay office. The building has residential room extending to the south, suggesting that the chief assayer lived adjacent to his work. South of the boiler room is a small charcoal storage building featuring an unusual exterior stairway to a hopper located along the north side of the eaves. Southeast of the mill, perched on the hillside, is a relatively substantial wood-frame house with a wood fence and full-length front porch along its west side. This was the superintendent's house. Because Theodore Hoover lived there in the early 1900s, the Park staff refers to it as the Hoover House. There are several small out-buildings on the hillside behind (east) the superintendent's house. Due east of the mill, and located on the hillside at the same elevation as the ore receiving level, is an ore receiving station. It consists of a small building and an ore bin with bottom discharge chutes for loading custom ore into cars bound for the mill by means of the east-side trestle. There are two cylindrical water tanks sitting on the hillside southeast of the mill and north of the superintendent's house. The grounds around the mill are scattered with debris and numerous pieces of equipment associated with the mill, the cyanide plant, and mining.

Chapter Seven: Conclusions

The Standard mill at Bodie is an outstanding example of the fully-developed California stamp mill of the nineteenth century. The mill is especially important because nearly all of its turn-of-the-century equipment is in place, so that operation of the mill can recorded as part of this project and can be interpreted to tourists who visit Bodie. The mill's equipment includes all the conventional pieces of equipment used for conventional amalgamation, and it also houses equipment, Frenier pumps, representing the cyanide process, which proved to be a vitally important addition to the technologies available to extracting gold from ore. The Frenier pumps were added shortly after 1900, when technological advances made it possible for the Standard

[115] "Standard Mill, 1903," photograph 61, box 2, Photograph Archives, Bodie State Historic Park; photograph of the Standard mill, ca. 1903, copy provided to author by Michael Piatt, Holland, MA.

Consolidated Mining Company deliver tailings from its stamp mill directly to its cyanide plant by a flume, rather than having to allow the tailings to settle in impoundments, as had been the practice for a quarter century.

The Standard mill is also a significant part of the broader landscape of Bodie. It was linked to water supplies, mine openings, tailings disposal areas, the cyanide plant, ancillary buildings, and the community by infrastructure that has not been thoroughly examined in this project. It would be useful for the interpretation of the Standard mill to expand the scope of the study to include those features that link physically the mill to its broader context.

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